A Scientific Metaphysical Naturalisation of Information

With a indication-based semantic theory of information and an informationist statement of physicalism.

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Abstract

The objective of this thesis is to present a naturalised metaphysics of information, or to naturalise information, by way of deploying a scientific metaphysics according to which contingency is privileged and a-priori conceptual analysis is excluded (or at least greatly diminished) in favour of contingent and defeasible metaphysics. The ontology of information is established according to the premises and mandate of the scientific metaphysics by inference to the best explanation, and in accordance with the idea that the primacy of physics constraint accommodates defeasibility of theorising in physics. This metaphysical approach is used to establish a field ontology as a basis for an informational structural realism. This is in turn, in combination with information theory and specifically mathematical and algorithmic theories of information, becomes the foundation of what will be called a source ontology, according to which the world is the totality of information sources. Information sources are to be understood as causally induced configurations of structure that are, or else reduce to and/or supervene upon, bounded (including distributed and non-contiguous) regions of the heterogeneous quantum field (all quantum fields combined) and fluctuating vacuum, all in accordance with the above-mentioned quantum field-ontic informational structural realism (FOSIR.) Arguments are presented for realism, physicalism, and reductionism about information on the basis of the stated contingent scientific metaphysics. In terms of philosophical argumentation, realism about information is argued for primarily by way

of an indispensability argument that defers to the practice of scientists and regards concepts of information as just as indispensable in their theories as contingent representations of structure. Physicalism and reductionism about information are adduced by way of the identity thesis that identifies the substance of the structure of ontic structural realism as identical to selections of structure existing in re to combined heterogeneous quantum fields, and to the total heterogeneous quantum field comprised of all such fields. Adjunctly, an informational statement of physicalism is arrived at, and a theory of semantic information is proposed, according to which information is intrinsically semantic and alethically neutral.

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Chapter 5 of this thesis is published as Long, 2014. I was the sole author and researcher on that paper, but grateful to the feedback from two anonymous reviewers and my supervisor, Professor Paul E. Griffiths. Other elements of the thesis (mostly from Chapter 6) were published as Long, 2018, for which paper I was also the sole author and researcher. My thanks to two anonymous reviewers and the editor of Erkenntnis, Professor Michael Esfeld.

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Contents

List of Acronyms

CICS Causally Induced Configuration of Structure (Intro. §4 p27, Intro. §4 p27)

EI Eliatic Information Principle or (§4.4 p162)

FOSIR Field Ontic Structural Informational Realism

IS1 Statement of Ontic structural Informational Realism (§3.5 p134)

IS2 Statement of Field Ontic Structural Informational Realism (§3.5 p134)

I-CICS *I*-existential statement of causally induced configuration of structure

H1 The CICS argument (Intro. §4 p27, Intro. §4 p27, Intro. §4 p28)

H2 The structure-QFT identity argument (Intro. §4 p27, Intro. §4 p27)

H3 The Source Ontology or ontic structural informational realism (OSIR) argument by IBE and indispensability (Intro. §4 p27, Intro. §4 p27)

H4 The field-ontic structural informational realism (FOSIR) argument (Intro. §4 p27, Intro. §4 p27)

H5 The intrinsic semantics argument (Intro. §4 p27, Intro. §4 p27)

I- Predicate/prefix denoting objective mind, language, computation, and theory independence (informationally independent and objective.) (Intro. §1.3 p37)

IA Indispensability Argument (Intro. §1 p16)

IBE Inference to the best explanation (Intro. §1 p16)

PNC Principle of Natural Closure

PPC Primacy of Physics Principle

QFT Quantum Field Theory

QM Quantum Mechanics

SIE Structural Informational Eliatic Principle (§4.4 p160)

TWSI The Theory of Weakly Semantic Information (§5.7 p200)

TSSI The Theory of Strongly Semantic Information (§5.7 p200)

List of Figures

Part I

Introduction

Difficulties associated with the newness of the discipline of the philosophy of information and information theory are well documented by philosophers of information, scientists, and mathematicians: especially with respect to how broad, ill-defined, and confused many of its concepts are (Floridi, 2011c; Adami, 2016; Dretske, 1981; Lombardi, 2004; Timpson, 2013; Griffiths, 2001; Adriaans, 2010; Floridi, 2009a; Vitanyi, 2000; Lombardi et al., 2016; Ferguson, 2015; Adams and de Moraes, 2016; Kraemer, 2015; Caticha, 2014.) To make matters more challenging, in pursuing my project of developing a naturalistic metaphysics of information, I intend application of - and a limited development of - a comparatively new kind of metaphysics (not of my own design): the *scientific* metaphysics suggested recently in the work of both ontic and informational structural realists James Ladyman and Don Ross, with reference also to the work of Steven French and Paul Humphreys (Ladyman and Ross, 2013; Ladyman, 2011; Ross et al., 2013; Humphreys, 2013; French, 2014.)

There is significant philosophical value in coherently identifying any central conception and definition of information that somehow corresponds to some independently existing thing (or category) in the world (Gillies, 2010, 8; Caticha, 2014, 38.) More straightforwardly, there is a benefit in identifying, if it exists, whatever the real thing is in the world, and especially the material world, that satisfies certain intuitive, but, more importantly, scientific, criteria and requirements for properties and characteristics that information must have: again, on scientific grounds. I will specify what these scientific grounds are by way of establishing a scientific metaphysics specifically for approaching the question of the nature of information.

Often in physics and molecular bioscience - even when there is a context that suggests some kind of statistical conception of information - it seems evident that there is some conception of some thing being transmitted or transferred from one spatiotemporal location to another: something apart from a reduction in the objective uncertainty about the next state of a dynamic state of affairs. The term ‘information’ is used as the basis for many scientific explanations, to the extent that in philosophy at least it has become something of a ‘weasel word’ in many applications. Information is often the stipulated arbitrary and undefined ontic basis for many descriptions and explanations in philosophy and science.

I have some sympathy for what has come to be known as ‘Canberra Plan’ metaphysics, according to which so called a-priori judgements and conceptual analysis are necessarily informed by or include upstream contingently acquired empirical evidence or information (Braddon-Mitchell and Nola, 2009; Jackson, 1994; Chalmers and Jackson, 2001.) However, I am not interested in analysing platitudes for epistemic applications, and I am only interested in intuitions when they belong to scientists making metaphysical judgements while doing science, and perhaps in the intuition that pluralism about the nature of information is probably true at higher levels of abstraction, explanation, and/or description.

I have no intention of pursuing a naturalised (reliabilist) epistemology based based upon a naturalisation of information as leading philosophers of information have done (although I think the project will be contingently successful.) I am interested in the naturalisation of information only, and on a very specific basis: that basis being an identity thesis that locates the physical structure of physicalist ontic structural realism *in re* to/within heterogeneous bounded regions of quantum fields comprising together the universal quantum field and vacuum. I'll achieve this by combining a field ontology forquantum field theory (QFT) with an informational adaptation of ontic structural realism, and with what I will call a *source ontology.* I am going to do, and refer to, only as much quantum field theory (I'll do precious little mathematics) as I have to and am able to. I will mostly stand on the shoulders of philosophers of physics and popularising physicists, with some harder material from the philosophy of physics and science, and scientific realism, ad-mixed.

When it comes to naturalising information, at minimum I agree with David Papineau's weaker non-a-priorism about epistemology and metaphysics which states that the a-priori is meaningful (meaning it is not nonsense and not epistemically vacuous) but that it is unimportant and irrelevant to philosophy. More strongly, and specifically for naturalising information, I don't reject - as Papineau does - Michael Devitt's assertion that there is no a-priori - or more precisely that there is no such thing as a-priori knowledge about scientific metaphysical facts, among others (Devitt, 1998; Devitt, 2005; Papineau, 1993.) I think Devitt's proposed abduction holds: knowledge about things like mathematical and logical truths that seems a priori is empirical after all and based on upstream empirical evidence (see also Chalmers and Jackson, 2001), while explanations for how a priori knowledge about such things could obtain sans empirical acquisition are unsatisfying. I take it that this approach coheres (adequately) with the 'viking' (raider) metaphysics of Steven French, according to which we can 'raid' the store of a-priori metaphysical assertions and hypotheses about the world to acquire that in it which is apt to be used in a contingent or scientific metaphysical manner (French, 2014.) Devitt and Papineau's respective non-a-priorist (anti-a-priorist in Devitt's case) epistemologies are a continuation of the best part of the debate between Rudolph Carnap and W.V.O Quine about the coherence of metaphysics and its relevance to science and philosophy (Quine, 1951; Alspector-Kelly, 2001; Devitt, 2010.)

1 Metaphilosophy and Methodology - Scientific Metaphysics

Something very like David Papineau and Michael Devitt's respective non-a-priori and anti-a-priori stances are applied in contemporary scientific realism for metaphysics under the head of what is now called scientific metaphysics, the proponents of which are usually ontic structural realists of some non-eliminative (about objects) stripe. There are correspondingly different - stronger and weaker - versions of scientific metaphysics available. Ladyman and Ross' and Paul Humphreys' versions accommodate something closer to Devitt's eliminativism or total epistemic eschewal of a priori conceptual analysis, and thus tends also to be friendly to Rudolph Carnap's dim view of a-priori metaphysical analyses (Humphreys, 2013; Ladyman and Ross, 2013.) While the interpretation offered by Steven French retains those analytic a priori conceptual analyses that are apt to be appropriated to contingent applications (French calls this appropriation of a priori constructs to contingent metaphysics 'Viking metaphysics' French, 2014.) I will favour such a metaphysics (more so the epistemically Devitt-aligned versions of Ladyman and Ross and Humphreys) and thus largely avoid a-priori analytic metaphysics and conceptual analysis in favour of deferring to the ontology identified by most physics.

My chosen ontology of information will be arrived at by exploiting formal theories of information and quantum field theory to identify what has come to be known in the literature as a *field ontology* by way of an unusual identity thesis: between the structure about which ontic structural realists like both French and Ladyman and Ross are realist, and selected structure existing *in re* in the quantum field (until - in accordance with defeasible science - something else is discovered to provide a better basis that quantum field theory) (Cao, 1997; Wayne, 2008; Teller, 2010; Lam and Esfeld, 2012.) So, metametaphysically, my approach is intended to be neither stipulative, a-priori, nor based upon conceptual analysis.

There is wide disagreement within philosophy and across the sciences about the nature of information - enough to lead many theorists to conclude that eliminativism and anti-realism about information, or something converging up them, must be true (Levy, 2011; Sommaruga, 2009.) Hence the propensity for leading theorists like Luciano Floridi to reject any idea of a central or overarching concept of information, favouring instead non-reductionism and pluralism (Floridi, 2004a; Floridi, 2011a, 217.) Moreover, there is enough disagreement among physicists and philosophers of physics about the ontological implications of both information theory and quantum theory, including (but not limited to) quantum information theory, such that a metaphysical discussion about both the nature of the quantum field and of information and how they might be associated is meaningful in philosophical *and* in scientific terms (Esfeld, 2014; Wayne, 2008; Teller, 1995; Fraser, 2004a; Kuhlmann, 2010b; Lyre, 2004; Rickles, 2008c; Everett, 2012; Redhead, 1995.)

It does not follow from the definitional uncertainty and semantic pluralism in the field that one should deploy either a-priori analytic methods (apart from logic), or conceptual analysis, for the task of adducing a metaphysics (Rickles, 2008a, 1-2; Ross et al., 2013; Humphreys, 2013.) While I have some sympathies and a predilection for Canberra Plan metaphysics, my methodological and metaphilosophical approach will involve ontological minimalism approaching nominalism. However, as I will argue at §3.4.1 p117, §1.2 p34, and §4.3.1 p147, nominalism is not an accurate label for the approach, which is information-theoretic in its motivation, and has a scientific metaphysical - and therefore largely *scientific realist* - basis (although, as I will demonstrate in chapters 1, 2 and 5, leading field ontologies and scientific structural realisms differ widely in their ontological commitments.)

As briefly mentioned above I will identify and establish the scientific criteria and requirements for the existence nature of information largely by recourse to inference to the best explanation (IBE) and a specific kind of indispensability argument (§2 p23, §3 p28, §4 p29, §2.1 p55.) I take both inference to the best explanation, induction, and indispensability arguments, all to be befitting of, and apt for deployment in accordance with, scientific metaphysical premises and principles of the kind I will present.

The locus classicus (and original) indispensability argument is undoubtedly the Quine-Putnam indispensability argument for realism about mathematical entities (Putnam, 1979, 323–358; Colyvan, 2001, 10-20.) According to the Quine-Putnam indispensability argument, for what is effectively a form of Platonist realism about mathematical entities, we should believe in the existence of Platonic abstract mathematical entities because reference to those entities is ineliminable in our best scientific theories, implying that realism about such entities is required for the solutions, explanations, and saving of the phenomena that those theories include or embody. I will be deploying a different variant of this indispensability argument in keeping with the premises of the scientific metaphysics of information I will develop. Like the Quine-Putnam indispensability argument, it makes an inference to the existence of something in the world that fulfils the role of information, from the comprehensive use of references to structure, information, and informational dynamics and concepts in our best scientific theories.

My overall approach, then, involves identifying, in accordance with scientific metaphysical premises, the indispensability, in the hard and special sciences, of realism about information, informational quantities and qualities, and/or to information dynamics and phenomena, as evidenced by the use of either information-theoretic terms and principles directly, or else terms and concepts associated with structural-causal dynamics that form the basis of such things as encoding, decoding, transfer, compression, translation, processing, programs, data, data representation, signification, generation, channels, messages, symbols, transmission, and signals. Information theory, in this connexion, is broadly construed as including classical Shannonian, algorithmic(Andre Kolmogorov and Ray Solomonov), computational, and hybrid conceptions, and any other formulations that arise on a defeasible or revisionary basis that are similarly reducible to the same basis in structure and structural dynamics. The next step (or, leg or pillar, perhaps) of the approach involves identifying a physicalist and reductionist (in keeping with the prescribed scientific metaphysics) metaphysical core conception of information on the basis of inference to the best explanation in conjunction with the aforementioned scientific metaphysics.

Importantly, I do not need the indispensability argument to directly either entail or imply, on its own, the specific field-ontological conception of information that I will propose according to scientific metaphysics and IBE. Thus:

i. The indispensability type argument (IA) and contingent (a-priori-analysis-eschewing) scientific metaphysics delivers - or is intended to strongly imply the truth of - *realism* about (structurally based) information in the hard and special sciences (and about such things as natural encoding, transmission, and natural decoding, among other dynamics.)

ii. Inference to the best explanation, in conjunction with the aforementioned scientific metaphysical approach, is, subsequently, intended to deliver, in the form of a field-ontological informational structural realism (FOSIR), a best candidate [1] for the basis of the nature of information (§3.1 p81, §3.2 p83, §4.3 p142, §3.5 p133.)

The indispensability argument I deploy (i.) has nothing to do with inferring either the epistemic value, or the necessity, of realism about Platonic entities, especially since I will argue, on the basis of the associated scientific metaphysics, that Platonic entities could not, in-principle, be informational (§1.4 p47.[2]) Instead, it's indispensability, by way of reference and representation, of what, according again to our best science, are naturally obtaining information, and informational dynamics and phenomena - *even when these are do not involve explicit use of the term 'information'*. Importantly, I don't need to argue *directly* for the indispensability of the specific naturalised conception of the nature of information that I argue for by way inference to the best explanation (ii.) I'll attempt to establish that via scientific metaphysics coupled with IBE (Refer especially to §3.2 p83.)

However, critically, I suggest that if the indispensability argument goes through for realism about natural *I*-obtaining information, and then the argument from scientific metaphysics *and* IBE goes through for the field ontological conception of information in nature, then I get indispensability of the field-ontological informational-structuralist account of natural information *transitively*, for free, so to speak, with the assistance of the prescribed contingent scientific metaphysical premises. However, in accordance with the tenets of the scientific metaphysics I will propose, I get it for free *defeasibily*. If QFT ends up bowing to a greater physics, then that physics should serve as the new (contingent) ontic basis for informational structure and information. I doubt that there will be a need to revise out the concept of structure, and I do not need to rely on a-priori reasoning for this doubt: I can defer to an empiricist, contingent scientific metaphysics since structure is as foundational to naturalistic scientific practice as causation. In other words, on a defeasible, scientific metaphysical, non-a-priori basis, if field-ontic structural informational realism is the best candidate for fulfilling the role of being the ontic basis of information in nature, then

[1] Something like the best-deserver of Canberra plan metaphysics.

[2] For the philosopher of mathematics now wondering what mathematical entities are according to the metaphysics that I will offer: they are informational but not Platonic, on a basis not dissimilar to the way that is suggested by Aristotelian *in re* realism about mathematical entities, but with a basis in information dynamics and a form of informational ontic structural realism. I do not have the space to develop this, but it has a basis in the black-box encoding/encoder approach to theory representation that I do herein develop §6.2.1 p212. Other than that it has to remain a promissory note, with the attached caution that my ontological conception of information is not mathematical. According to my approach, mathematical abstracta and representations are abstractive encodings of information from structured sources. Mathematics is not the basis of information, ontologically speaking: only of its measures and metrics.

it (field ontic structural informational realism or FOSIR) is strongly implicated also on the basis of an indispensability argument for causal and structural information in our best scientific theories made on the same scientific metaphysical basis.

Importantly, the indispensability argument about information that I will develop (ii.) differs from its Quine-Putnam pro-Platonism forebear insofar as it is arguably *stronger*. It's stronger in the sense that (trivially, I suggest) structure, causal pathways, and causation are indispensable to science more than is mathematics. In fact, causal pathways, causation and structure, whatever they actually are, and however they are systematically characterised (and it's not unfair to baldly state that most scientists take both to be physical in some way), are not just indispensable, but are all *foundational*, to science and the practice of saving the phenomena. This makes evident the mutually supporting nature of the indispensability argument for realism about information (i.) and the inference to the best explanation argument for the nature of information as based upon informational structure (ii.) The reductive and defeasible conception of information according to IBE - the CICS or causally-induced configuration of structure conception - broadens the scope of application of the indispensability argument so that it applies not only to informational terms and references specifically, but to the structural and causal reductive basis thereof. There is no circularity involved, since i (IA) and ii (IBE) can stand independently of one another.

It's also important that there are different ways of interpreting the basis of the Quine-Putnam indispensability argument (Busch and Morrison, 2016; Busch, 2012; Colyvan, 2001, 1-12, 40-44.) The three commonly identified premises are Quinean naturalism, confirmational holism, and inference to the best explanation. Quinean naturalism bids us to regard science only as the sufficient basis for understanding nature and natural phenomena. Confirmational holism asserts that there are only arbitrary distinctions between natural concrete and abstract mathematical entities in scientific theories, and that realism about the former should be accompanied by realism about, and belief in, the latter, as part of the ontology. According to confirmational holism, all of the referents in a theory are taken together as real:

> Adopting confirmational holism ensures that there won't be any discrimination between empirical and non-empirical parts of a theory when it comes to confirmation (Busch, 2012, 5.)

Eliot Sober has used confirmational holism as a foil against Quine-Putnam indispensability of Platonic math abstracta, since there are non-mathematical versions of some theories that are as complete in scientific terms as their mathematical counterparts (Ibid, 4-6, Sober, 1993.)

Jacob Busch also reminds us of Penelope Maddy's argument that confirmational holism is flawed due to the fact that scientists often employ useful fictions that are not intended to pick out any real referent in the ontology (Maddy, 1992.) As such (per a distinction I will draw later that Maddy and other indispensability theorists do not draw) those entities or dynamics might be thought of as in the ontology of the *theory*, but not in what I will call the I-ontology: the mind, language, computation, and theory independent ontology from which representing structure in the theory are encoded. (See §1.3 p37.)

My indispensability argument for realism about information (ii. §1 p16) does not require confirmational holism, and nor does it require the absence thereof. A salient comparison would be between the ratio of confirming non-mathematical to mathematical theories, as compared to the ratio of confirming theories that do not reference dynamical structures, signaling, casual pathways, or other informational and transmission dynamics, against those that do make such references. Many theories readily omit reference to informational dynamics using the term 'information' itself, but if one includes the entire vocabulary of information theory, informational dynamics, and dynamical structural, and causal language that it can be reduced to or that constitute it in other ways (encoding, signalling, entropy, compression, data, transmission, transfer, channels, casual pathways, codes, transduction, sources, and so on), then the number of non-information-referencing confirming theories is, in-principle and practically, significantly reduced, along with the relevant ratio. Perhaps more significantly, the number of leading and important scientific theories in the hard and special sciences that make no terminological or representational direct or indirect reference to information dynamics and elements is few overall. This is even more the case if one includes statistically based theories that make use of convergences, divergences, and other comparative statistical measures between random variables such as Fisher and Kullback-Leibler information measures, since I will offer a way of construing frequentist statistics physicalistically (Ladyman and Ross, 2013 do something similar for their conception of statistics qua physical stochasticity; Kullback, 1959.) Put in a different way - if there is a theory that can be stated using informational, information theoretic, and information-dynamical terms and references on the requisite basis, then any confirming theory that does not overtly deploy such terms and references is likely to be found to be relying on concepts and terms that reduce in some way to (or at least supervene upon) informational terms and concepts, or else to provide a reductive basis for them. It will be as difficult to remove from the confirming theory concepts of, and references to, structure, causation, and causal pathways, and according to my argument for my characterisation of the nature of information, information reduces to the causally induced configuration of structure. (§3.3 p101.) My indispensability argument for realism about information (ii.) relies upon Quinean naturalism, and in-principle upon what Colyvan refers to as Quine's "ontological commitment of theories" - as delivered by the ontological commitment of the existentially quantified entities of theories regimented in Quinean fashion using first-order formal logic. It can also be regarded as involving its own inference to the best explanation for why there are so often informational terms and representations in working theories. Thus IBE will play a dual role at the level of metametaphysics and methodology herein. The first role will be to point to a specific field-ontological and ontic structural conception of the nature of information. The second and separate role will be to constitute part of an indispensability argument for realism about information.

2 Physicalist, Structuralist Realism about Information

In terms of the metaphysics of (the nature of) information itself, the central and most radical proposal I will defend is that information only exists physically. More specifically, that it necessarily existentially depends upon and reduces to physical spatiotemporal structures and structures that reduce to such structures. These structures, as I have mentioned, I take to be or else reduce (ontologically) to structures that inhere *in re* in the quantum field. I will refer to the totality of all quantum fields for all standard model particle realisations and other non-standard properties as *the* quantum field and vacuum. I'll argue that the structures that ontic structural realists should be realist about inhere in the quantum field and vacuum thus defined in the sense that they existentially depend upon it and exist *in re* in it. More specifically, within heterogeneous bounded regions of it, including regions that are non-contiguous, non-continuous, and distributed. 3.2.1. In other words I will be combining what is called a specific field ontology for quantum field theory with ontic structural realist ontology on a scientific metaphysical and contingent basis to naturalise information.

In pursuing this end, issues arise with the scientific ontological status of fields, quantum systems, spacetime, and their representation in physics. Later in the thesis I will explain why physicalism about information is not simply trivial, and not just a restatement of token physicalism (1.1, 7.4.2.) My claim throughout will be that my scientific metaphysics allows me to defer to discoveries and applied mathematical theories in science to discover the nature and ontological content of information in accordance with the defeasible nature of science and scientific theorising. This *defeasibility* of science does a lot of work in the interpretation of scientific metaphysics that I will deploy (2.2.)

In defining and identifying what they are ontic structural scientific realists about, ontic structural realists Ladyman and Ross stop at non-redundant statistics - which exists physically and mind and language independently as the basis of their scientific metaphysics and non eliminative (about objects) ontic structural realism (NOSR), which is not specifically an informational NOSR. French's scientific realist ontology instead stops at modal innateism (French, 2014.) Floridi, whose adaptation of NOSR is informational (informational structural realism) stops at a transcendentalist conception of data which reduces to infons and ontologically neutral differences *de re* (6.2.) I stop at whatever physics ends up contingently discovering - defeasibly - is the objective ontological content (causally induced physical configuration of) of spacetime, and more specifically heterogeneous bounded regions of the quantum field, as referred to in our best quantum field theories (Cao, 2003a, 25-7, **29-30**.)

To grasp the relevance of my proposed version of physicalism about information at the outset, consider the question of dualism about mind versus identity theory and epiphenomenalism. The debate about mind and the explanatory gap usually centres upon whether or not the mind reduces in principle and practically to the physical neurological processing of information. The physicalism about information that I will espouse means my anti-dualist claim is even stronger: the mind is the physical processing of necessarily physical information. It's not just the mind that reduces to and is identical with (in identity theoretic and epiphenominal terms) physical systems and stochastic and non-stochastic physical processes (contemporary information theory includes both kinds of information source), but the information involved is necessarily only physical, as there is no such thing as non-physical or non-physically-reducing information. I am not the first person to suggest physicalism about information (Gillies, 2010, 8), but I am not aware of anyone else that has attempted to do so by combining quantum field theory (QFT) with structural realism and scientific metaphysics, and without putting information at the bottom of the ontology as Floridi has done (Bawden and Robinson, 2013; DiVincenzo and Loss, 1998; Landauer, 1999; Esfeld and Lam, 2009; Esfeld and Lam, 2010; Allo, 2010; Floridi, 2008a.)

This physicalist (and significantly reductionist) move will likely seem wrong to many, for a number of reasons including - but not limited to - concerns about obvious pluralist deployment of the term 'information' in the sciences, non-reductive physicalism and emergent phenomena, and the overtly statistical and algorithmic basis of much of information theory. Not to mention the infamous difficulties associated with defining the physical itself (7.1.) I do not intend to argue that pluralism about information in scientific praxis - even within hard scientific subdisciplines - does not occur. It obviously does, although some theorists working at a more mathematical level commonly try to unify algorithmic information or complexity theory with classical information theory (Chaitin, 1975; Grünwald and Vitányi, 2003; Calude, 2009, 86-9.) However, when information scientists, quantum information theorists, black hole physicists, and those dealing with the question of quantum entanglement and Bell's theorems (and the possibility of superluminal information transmission - see Al-Safi and Short, 2011, 1-3) all start referring to information as a central element of their theory, then it looks like more than just intuition that is suggesting a common referent. At the very least the ontology of their various theories requires - or is encoding representations and concepts from or reading off - a common conceptual and ontological referent for the term 'information'. Then, when many of them start discussing information as entropy and trying to identify the right alternative between Von Neumann, Boltzmann, and Shannon entropy, or even trying to reconcile these in the context of - say - thermodynamics: then it looks like it is not just deference to Shannon's theory that is the common ontological and methodological currency (Sagawa and Ueda, 2009; Tribus, 1963; Bennett et al., 1993.)

This alone does not tend to imply, let alone entail, the truth of physicalism about information. There are many detractors in the sciences who have concluded that the attempts at synthesis are an inappropriate confusion (and in some cases this may well be true. See Oppenheim, 2010, 84-5.) However, in molecular bioscience, numerous geneticists and biophysicists have tried to do perform exactly the same kinds of unification or synthesis in order to capture adequate detail and express a more complete theoretical and natural ontology

- especially where physics and genetics meet in studies of protein folding and other areas like neuroscience (Galas et al., 2010; Hodgson and Knudsen, 2008; Zhao et al., 2006.)

These observations must - at this early point in my presentation - be (temporarily) informal. However, consider that in molecular bioscience, biophysics, quantum information theory, and quantum computing theory, measures of information are almost comprehensively measures of either entropy, or measures of specifically structural complexity, or unifications of the two (Plastino et al., 1997; 129-30; Dierckx et al., 2008, 1-2, 8-9; Landauer, 1999; Vitanyi and Li, 2009; Adami and Steeg, 2014; Aguirre et al., 2015; Al-Safi and Short, 2011; Altschul et al., 2009; Bavaud, 2009; Bawden and Robinson, 2013; Artiga, 2014; Barbieri, 2012; Bekenstein, 2004; Eidhammer et al., 2004; Collier, 2008; Zurek, 1989; Zhao et al., 2006; Wheeler, 1989; Uhlmann, 1970; Frieden and Gatenby, 2013.) Consider also the relationship between complexity and entropy in complexity theory and physics (Anand et al., 2011; Barnum et al., 2012.)

There are at least two initial challenges in presenting such a metaphysical conception of information (I deal with them both in Chapters 1 and 4.) Initial responses often involve a charge of token physicalism, and just as in the philosophy of mathematics, there is platonism to contend with. The charge of token physicalism is not a serious threat. It makes a significant difference to the ontology of scientific theories that information is and reduces to something physical rather than - say - some kind of Platonic abstracta, or some kind of subjective epistemic content and/or subjective statistical outcome (elements of each of which may be taken to involve Platonic entities.) Moreover, there are a number of non-reductive physicalists who take information to be part of whatever exists in the world that cannot be reduced, or even to be additionally or else alternatively something subjective and/or mind-dependent. In some cases such physicalists allow that information either does or can exist in some kind of Platonic abstract space as some kind of Platonic abstracta. In chapter 3 and 4 I move to apply the principles of scientific metaphysics to non eliminative structural realism (NOSR), thus arriving at what I call ontic structural informational realism (OSIR) by field ontology (FOSIR.) I distinguish OSIR from the well known ISR (informational structural realism) of Floridi (Floridi, 2008a. I leave the work of comparing FOSIR to other non-field ontic informational structural realisms to 6.4.)

What I am at this point not informally intuiting - but instead observing commensurate with the tenets of scientific metaphysics (Chapter 1-2) - is that there appears to be a scientific praxis-driven conceptual convergence, as well as a set of common conclusions from different hypothetico-deductive inductions in different fields, towards a physicalist - or at least a scientific realist - understanding of the nature of information. As I will also proceed to argue in the early chapters, however, what is being deployed is not some commitment to a natural kind (in line with Wiener's famous dictum Wiener, 1961), but to the existence of something that scientists consider to be at least as real as structure - and perhaps more real than physical causation (counterfactual theses and Hume's doubts notwithstanding, causation seems to be ineliminable from our best scientific theories.) This is the argument from indispensability of structure and information in scientific theorising that I referred to in the previous section (§1 p16), and it calls inference to the best explanation (and best candidate empirically determined contingent deserver) for ontological explanatory and existential status (See H3 at 4 below.)

This view will inform my hypothesis that information is the causally-induced configuration of physical structure (CICS) or of structure that reduces to such (H1 at 4 below), and that the structure at bottom (as far as our best science can identify) must be embedded in and realised in the universal quantum field. This is the ontology that I think really should be taken to be delivered by a Ladyman and Ross (Ladyman and Ross from now on) style formulation of scientific metaphysics. A way of stating this view is to say that structure and causation are real, and information is just as real and is the causally induced configuration of structure, and can be encoded, processed (computationally and algorithmically), transmitted, and represented.

The difference between my approach to scientific and physicalist structural realism and that of Ladyman and Ross is that I will resist their move to a mathematical or statistical-at-bottom ontology (In this approach I am in agreement with Tian Yu Cao Cao, 2010, 202-203.) I likewise resist the respective innate modalist and many worlds reductions of Steven French and Michael Esfeld (French, 2014.) Despite their scientific realism via ontic structural realism, Ladyman and Ross seem to embrace statistical ontology on the basis of what seem to be partly instrumentalist intuitions as well as scientific metaphysics (French and Ladyman, 2003a, and see 7.1.) They may have an out on the basis of a commitment to statistics as something that exists mind, language, theory, and computation independently in the world as an intrinsic component of stochasticity in natural systems and processes. I will be identifying such things as information sources. I'll identify fields (classical fields and bounded non-uniform heterogeneous regions of the universal quantum field), not relations, as the reductive basis of structure in a scientific realist ontology(3.3; 6.6.) As such, the non-eliminative ontic structural realism that I will adopt is what has come to be called a field ontology (see Cao, 2003c, pp. 17–19; Esfeld and Lam, 2008.) Just as NOSR does with respect to structure, I reject subjectivism about information in all of its currently known forms: information can exist apart from minds, observers, receivers, and computation (certainly agent centric and artificial computation, but I reject that there is any need to regard the universe and nature as a computer, and think that arguments for such are abductive rather than inductive and break down as a bad analogy.)

In this I am again in agreement with Tian Yu Cao (Cao, 2003a, 25-8; Cao, 2003b; Cao, 2003c.) I will also largely avoid and reject the modal - or modality centric - approach of philosophers like Micheal Esfeld and Dean Rickles (Esfeld, 2009b; Rickles, 2008a) which is significant in the light of developments in the metaphysics of information in quantum mechanics and the philosophy thereof, since the possible worlds model in quantum theory currently enjoys significant support (Deutsch, 1985b; Wallace, 2012; Wallace and Timpson, 2007; French, 2014.) My approach to a physicalist, scientific realist, *scientific* metaphysics of information also meshes with a reductive and physicalist conception of information as endorsed by quantum computation pioneer Rolf Landauer, and analysed by DiVincenzo and Daniel Loss in relation to quantum systems (Landauer, 1991; Landauer, 1996, DiVincenzo and Loss, 1998; Vitanyi, 2000. See also Bub, 2005.)

There are related and relevant meta-theoretic and metaphysical questions in quantum mechanics, field theory (classical and quantum), quantum information theory, and black hole physics associated with the nature of mathematical abstracta, and these questions intersect with the way that the nature of information is treated within the theories themselves. The work of pioneer quantum information theorist Rolf Landauer is one of the earliest and clearest statements of physicalism about information. Landauer required that information (which is in a significant sense identical to data representation, according to Landauer) is in fact physical, and that there can be no data representation without physical structure - a principle that Floridi has opposed under the rubric of ontological neutrality (ON) within a Kantian transcendentalist metaphysical framework. Floridi's Kantian framework allows that one can in-principle have representation of data without material implementation (Floridi, 2011b, 90.) As I will discuss in chapter 5, it is not clear what it means to naturalise data either. Moreover, the key theories referred to by scientists and philosophers alike - that of Hartley, Shannon, Kolmogorov, and Fisher - are grounded in physical sciences and applied mathematics for the physical sciences.

I intend a (scientific metaphysical) conceptual progression in this thesis from the idea of ontic structural informational realism (OSIR) to *field* ontic structural realism about information, or what I am going to call a field ontic structural informational realism (FOSIR.) My intention is to argue and establish first that structure inheres *in re* in the physical ontology about which ontic structural realist scientific realists are realist: not something in theories but that in the world which the structure of theories maps to and represents according to ontic structural realism (and according to some versions of intrumentalism.) Then the next move is supposed to be to establish an identity thesis in accordance with the scientific metaphysics I adhere to, and incorporate the quantum field into the structural realism as the very basis for the substance and realisation of the structure. However, this identity thesis is so conceptually critical that it cannot be deferred until after the introduction of an ontic structural realism.

Chapter 3 introduces my own adaptation of non eliminative ontic structural realism - ontic structural informational realism (OSIR) - and its field ontological extension: Field Ontic Structural Informational Realism (FOSIR.) It becomes field ontic structural informational realism. It involves proposing a radical identity between physical structure referred to in theories and (defeasibly) the quantum field itself. The chapter concludes with the presentation of two revisionary physicalist hypotheses. The first is an informational version of David Armstrong's eliatic principle: the idea that the only things that exist are causally interactive. The other is an informational restatement of physicalism derived from the definition offered by Frank Jackson, which definition goes that if one duplicates all the physical stuff in the world, one has therefore duplicated absolutely everything (Jackson, 1998.)

3 Semantic Information: It's the Same Information

It is widely thought that there must be a meaningful and valid conception and theory of semantic information, or that at least one should be contructed (Shannon and Weaver, 1949 [3].) In the third chapter, I will present an argument that all information realised by or obtaining due to (existentially depending upon) causally configured structure is intrinsically semantic. Quantitative theories like that of Shannon are understood by most theorists to elide any semantic aspect, although Dretske's theory links semantic content to both quantity of information and Shannon's measure, and Pieter Adriaans has presented a challenging argument that Shannon information and associated quantitative measures include an adequate semantics (Adriaans, 2010.) Theorists who do not agree that quantitative theories adequately account for the semantic value of information propose various other semantic conceptions which involve various views of the alethic value of information: its relationship to truth. Floridi and Dretske assert that information is always true. Mathematician Keith Devlin allows that information is bivalent (Devlin, 1991, 80-1.) In Chapter 5 I suggest it is neither. I take the assertion that information can only be true to be an indication that something is wrong: information is not a truthbearer at all, but instead is a truthmaker [4].

Christoph Adami has suggested that the philosophy of information has many conceptual parallels to the philosophy of mathematics, and that the philosophy of information should be approached on a similar analytic basis (Adami, 2016.) There exist numerous scientific and applied mathematical approaches to understanding and defining the nature of information including algorithmic information theory and various logics of information (Sommaruga, 2009 includes several offerings in the logic of information, and Floridi defers to Devlin's adaptation of Barwise and Perry's situation theory in Devlin, 1991; See also Allo, 2011), not to mention computational conceptions that are not statistical in nature (Turing computability for example, and the minimum description length principle.) Each of them has - or seems to have initially - a different ontology of information if mathematical constructs of any kind are taken to be the ontic reductive basis of the nature of information, which is often the case. In Andre Kolmogorov's algorithmic information theory, information is the structure of data objects which are physical, while in Shannon's theory information is seemingly both physical entropy, a statistical measure of entropy, and a reduction in objective statistical uncertainty (at minimum. Kolmogorov, 1968, 6-8; Shannon and Weaver, 1949.)

So given that there is often apparently not a lot of scientific consensus about the nature of information even at what Floridi refers to as lower levels of abstraction - or at maximum conceptual and ontic reduction - in formal theories, then it is not surprising that theorist tend towards pluralism, eliminativism, or nominalisms (Floridi, 2011c.) If information is something like a reduction

[3] Refer to the Preface by Warren Weaver

[4] For further background, refer to (Floridi, 2011c,92-3)

in objective uncertainty (sometimes a subjectivist interpretation of the probabilities is asserted) based upon a current state of a source or a signal - then it is not clear how that translates to reductions of uncertainty with respect to different structures and structured states of affairs (Christopher Timpson, 2013, 26, agrees about the rejection of the *subjectivist* classical interpretation.) This is a non-trivial problem that Fred Dretske arguably failed to resolve despite systematic work inspired by Shannon's theory and with a naturalising metaphysics that largely obeyed the scientific metaphysics of Ladyman and Ross in the naturalistic way that it drew upon that theory (Dretske, 1981; Timpson, 2013 10, 38.)

I will not be concerned with naturalised epistemology as Fred Dretske was (this takes me too far afield into applications which are not my central concern), but his attempts to naturalise epistemology by naturalising information are enlightening with respect to the metaphysical problems of the nature of information. Dretske sought to retain naturalisation of information, representations, doxastic content (or his alternative thereto) and epistemic content, while regarding information as an objective abstract commodity. Yet he asserted that information based beliefs and knowledge rely upon a subjectivist element. This apparent subjectivist element is what Dretske called the k factor. According to Dretske "A signal r carries the information that s is F = The conditional probability of s 's being F, given r (and k), is 1 (but, given k alone, < 1)" and "Here k is a variable that takes into account how what an agent already knows can determine the information carried (for that agent) by a signal.1" (D'Alfonso, 2016, 307-8.) Technically, k is what the receiver and destination 'know' about the states that can obtain at the source. This is the source alphabet or state possibility space, or, rather, in subjectivist psychologistic terms, an imperfect subset thereof. It's a partial knowledge of the codes required to decode the source generated signal-borne sequences and messages: or rather in Dretske's case single signals. The upshot of this is that while Dretske's naturalised conception of information is classical (with adaptations for a single signal content rather than an average across signals, sequences and messages), statistical, and objectivist, his naturalised conception of *semantic* information is apparently necessarily subjectivist and probably psychologistic (although the latter is less clear, since the term 'knows' with respect to what the receiver knows can be metaphorically interpreted.)

The statistical core of Dretske's naturalised objectivist conception of information is prescient. It anticipates the somewhat later assertion of scientific metaphysicians and realists James Ladyman and Don Ross that "the world is the totality of nonredundant statistics". If statistics exist somehow mind, language, theory, and computation independently, then this would seem to provide a vindication of Dretske's objectivist conception. My approach will involve accommodating these statisticalist objectivist naturalising moves and views, but emphasising a more basic and - perhaps - less specific naturalised conception of causally induced structure, and relying - on a defeasible scientific metaphysical basis - on another very statistically orientated theory: Quantum Field Theory. I will not venture at any point to engage on a detailed level with quantum field theory, and I will largely stand on the shoulders of those better qualified, citing their metaphysical observations and explanations. My engagement with the science will not be completely bereft of detail, however, as is dictated by my stated predilection for a scientific metaphysics.

4 Key (Scientific-contingent) Metaphysical Arguments: CICS, OSIR, and FOSIR

The metaphysics of information I am arguing for, via scientific metaphysical premises, is based upon combining ontic structural realism with what has come to be called a field ontology. This is to support the further ontological idea that the world is the totality of all information sources, which in turn are, or reduce to, causally induced configurations of structure. The structure of the information sources inheres *in re* in some $n > 0$ region(s) of the heterogeneous quantum field(s) (or the vacuum - to be more general and universal) which permeate(s) all of spacetime, providing the substrate in which energetic excitations realise particles and their properties. The region(s) can be bounded, contiguous and continuous, or, alternatively, they can be distributed: including an arbitrary (depending upon such things as nomic constraints, system function, or properties and relations that are somehow significant) set of non-continuous and non-contiguous sub-structures selected from a larger structure(s) (The latter might arise with such things as binary systems in astronomy, entangled systems in quantum mechanics, and assemblies of neurons in the context of neuroscience.) I propose this contingently in terms of the whole of QFT, since there is a debate about whether the emergent excitations in standard model fields are what physicists call particles at all (Kuhlmann, 2015. See 6.1, 6.2 herein.) I will be claiming that my inclusion of scientific defeasibility of theories and explanations saves me from having to be very concerned about this, provided optimistic meta-induction about scientific theories is at least as good as pessimistic meta-induction, where good means prospectively correct and accurate given contingent information.

This thesis requires four significant arguments to sustain the proposed naturalising ontology of information (presented here in order of logical and ontological precedence/progression, which does reflect the order of their presentation in the thesis because of some of the complexities involved in combining OSR and a stochastic source-process ontology with a field ontology):

H1 The CICS argument: That information is the causally induced configuration of structure (CICS), and that such configurations of structure are the states of sources. (Chapters 1 and 6.)

H2 The structure-QFT identity argument: The best ontic candidate for best deserver for what constitutes the nature and substance of structure referred to in physicalist scientific realist ontic structural realism in general is and/or reduces to selections of physical features or structure *in re* (in) heterogeneous quantum fields. (Chapters 3 and 6)

H3 The Source Ontology or ontic structural informational realism (OSIR) argument by IBE and indispensability: That natural stochastic processes and systems are CICS sources (This is consolidated in 4)

H4 The field-ontic structural informational realism (FOSIR) argument: That the structure of causally configured (CICS) information sources per H3 is identical to *in re* selections of features or structure in heterogeneous quantum fields, and/or is identical to physical structures that reduce to such QFT *in re* structures. At reductive ontic bottom they are and/or reduce to bounded regions of heterogeneous quantum fields, or to combinations of such regions. (This is the work of 3 and 6)

H5 The instrinsic semantics argument: That information per the ontology argued for in H1-H4 is intrinsically semantic on the basis of indication and causal pathways, and yet alethically neutral, and is a truthmaker and not a truthbearer (This argument is presented in its entirety in Chapter 5.)

I have elected to largely (but not completely) support the (now) almost thoroughgoing statisticalist ontic structural realism of Ladyman and Ross by reference to Shannon's theory, other mathematical conceptions of information (including algorithmic conceptions and those that are hybrid), and quantum field theory. However, as I will explain at 3.2.2 I do not concur with the idea that the ontology sought by ontic structural realists should be taken to bottom out at physical statistics realised as stochasticity in natural phenomena. I'll argue that, at best, if statistics are physical in that way, they constitute only part of the total structure of any natural phenomena or system. I have elected to avoid the Kantian transcendental commitments of Floridi, because I'll be claiming that - contingently and not on the basis of a priori conceptual analysis:

P1. Real information necessarily always is or reduces to the causally induced configuration of physical structure (I will be referring to this often using the acronym CICS, and will often use the phrase "CICS information" to indicate I am specifically referring to information according to this conception and definition.)

P2. A sufficient and necessary condition of its existence is that is transmittable

P3. A necessary condition of that transmissability is physical causal pathways and specifically physical causation (as a reductive basis for causation at least), and that

P4. The world is the totality of stochastic CICS information sources that reduce to structurally heterogeneous bounded regions of the quantum field (this latter assertion is what I will be referring to as the/my identity thesis about structure.)

Regarding P1, as mentioned above, I'll be arguing that in accordance with scientific metaphysical premises of the kind that Ladyman and Ross endorse, and with reference to inference to the best explanation and the primacy of physics constraint combined with a specific indispensability argument, that our best defeasible scientific theory (quantum field theory) avails us of a basis for a physicalist identity thesis (P4) about the ontic structure that ontic structural realists like Ladyman and Ross are interested in. That basis is the structure inhering *in re* in the quantum field and bounded regions thereof: the ontic structure that is the existential basis for, and a necessary condition for, the obtaining of CICS information, is literally identical to that physical structure inhering *in re* the quantum field and vacuum (including and incorporating - or being constitutive of - what is often called 'quantum foam' Bynum, 2014, 131.)

Part II

A Scientific Metaphysical NOSR for Information: Developing Field-Ontic Structural Informational Realism

Chapter 1

Scientific Metaphysics of Information

1.1 Introduction

The purpose of this chapter is to begin to set naturalistic metaphysical, metametaphysical, methodological, and information-theoretic foundations for my investigation of the nature of information. I will continue this project in §2 p55 and §3 p81, where I will give some support for what I have called my indispensability argument (See argument *H3* at §4 p27.) Metametaphysically the intended approach is contingent scientific metaphysics. The methodology thus involves minimising a-priori analytic approaches and conceptual analysis. My objective is to present and defend a reductionist, physicalist, and anti-platonist metaphysics and ontology of information. That is: a scientific metaphysical characterisation of the nature of what underlies scientific references to information, or a statement of what information is. Or, more precisely, what information reduces to - and how it exists.

I agree with Ross and Ladyman's assertion that the only coherent metaphysics is that which intends to build bridges between and unify elements of scientific theories regarding as (defeasibly) real only ontologies of the best available theories in the physical sciences (their principle of natural closure or PNC) (Ladyman et al., 2007, 28.) Ladyman and Ross ultimately conclude that the world is the totality of all nonredundant statistics precisely because they favour a contingent metaphysics, and reject a-priori analysis derived from armchair speculation (included a-priori conceptual analysis.) They privilege physics as a source of material facts and knowledge about the nature of reality (the primacy of physics constraint, or PPC) (Ladyman et al., 2007, 5.)

Ladyman and Ross's metaphilosophical mandate - that I also adopt - is that the only good metaphysics is properly scientifically motivated non-a-priori metaphysics (with reasonable tolerance for scientifically informed hypothetico-deductive approaches) and that if any conceptual analysis is included it is with a view to unifying existing ontic concepts from scientific theories (which is also somewhat familiar from the Canberra Plan view of prior evidence based conceptual analysis and ontic-cum-explanatory best-deserver nomination.) I also agree with Humphreys that an a-posteriori/contingent scientific metaphysics is better because it inherits the methodological and epistemic property of theory and conclusion *defeasibility* (Humphreys, 2013, 55; See also Hacking, 2002.)

My first task in this chapter is to develop a reasonably systematic definition and formulation of my metaphysical approach. This will include an outline of a significant contribution to the philosophy of information in general - a calculus and (pre)logic of information dynamics encompassing what is commonly referred to as information flow - but covering numerous other important dynamics of information and information processing not covered by any logic of information offered at this time.

My next task is to begin to bring this scientific metaphysical approach to bear upon some a-priori reasoning and conceptual analysis (although I will not be deploying the aforementioned logic of information dynamics for the purpose. It gets limited use later in the thesis.) My targets will be Platonism about information (the view that information can exist Platonically) and Kantian transcendental realism about information which allows or requires that information can be realised in abstract spaces where an abstract space is considered to exit in that contemporary weak Platonic sense (that is - with no commitment to any claims about exactly *how* Platonic structures or entities might exist.) I have already indicated that the new scientific metaphysics proffered by Ladyman, Ross, Kincaid, Humphries and (to some extent) Collier has itself got a conceptual heritage in, and is contextual to, the Quine-Carnap debate about the salience of metaphysics and commitment to the existence of mathematical entities, the subsequent epistemologically orientated discussions of Papineau and Devitt, and the considerations of contingently informed a-priori conceptual and intuitive reasoning of the Canberra Planners. However, I will be favouring the stronger anti-a-priorist metaphysical-to-epistemological views of Devitt and the aforementioned scientific metaphysicians. This is because I regard that it is hard to deny that both the Canberra Plan's contingently informed a-priori conceptual analysis and French's Viking Metaphysics seem to be inherently subsumed under contingency: the real metaphysical work is being done by scientifically underwritten contingent-empirical evidence and information (I don't think that French opposes this outlook.)

1.2 Physicalism and Structure

One position unpopular with, and doubted by, many contemporary philosophers and philosophers of science is physicalism about information. Still more unloved is physical reductionism about information (Griffiths, 2001, Floridi, 2004a, Chalmers, 1996), but there are also many philosophers and scientists that regard it as contingently and/or in-principle true (Refer especially to Jackson, 1982, Landauer, 1991, Landauer, 1996, DiVincenzo and Loss, 1998, Bub, 2005, Devlin, 1991, 82-86; Cao, 2003a, 25-8; Papineau, 2010b; Esfeld, 1999.) Other applied scientists and mathematicians present apparently confused or contradictory viewpoints (Shannon et al., 1993a [1]), but with significant commitment to realism about information as something like physical entropy, physical stochastic system changes, or some kind of physical complexity (Kolmogorov, 1963 [2] See also Cover and Thomas, 2006.)

There are conceptions of information that regard that it can exist noetically, abstractly, and Platonically (Floridi, 2003; Floridi, 2011c, 88-90) or otherwise transcendentally (Gillies, 2010, 8.) Moreover, there are metaphysical theories that eliminate information from the ontology completely. Still others regard that some kind of nominalism about information as true, while other conceptions involve the necessary presence of either a conscious receiver-agent or an unconscious non-cognitive consumer or receiver for there to be any information (Dretske, 1981, 65 [3]; Shea, 2007a, Millikan, 2013.)

The reductionism about structure and information that I favour is ontic rather than epistemological. It is not commonly endorsed, and has serious detractors (Dennett, 1991, Floridi, 2008a [4].) Moreover, even some naturalising theories of information require cognitive-subjectivist premises about the existence of information that render epistemic content of some kind as a necessary condition for the obtaining of information such that they converge on a form of idealism about information (Deutsch, 2013, 4331, 4343, 4347-8, Dretske, 1981, 58-9; Peacocke, 2010, 256, 265; Deacon, 2010, 146-7.) However, I will seek to secure credibility using the best science available on its own defeasible terms (see §2 p55), thus debunking platonist, subjectivist and epistemic conception of the nature of information as being based upon what are in fact errant and unfounded a-priori metaphysical assumptions.

Because the expressly physicalist and reductionist non-eliminative ontic structural realism that I will present is the basis for the scientific metaphysics and defeasible characterisation of information that I present, it entails anti-subjectivism about *real* information (including semantic information.) There is a bidirectional entailment relationship regarding the ontological status of structure and

[1]Scientists and applied mathematicians like Shannon often have a coherent materialist metaphysics, but are less concerned with philosophical discourse and expression than with problem solving in their domain of application

[2]As I will discuss in Chapter 3 - Kolmogorov was a very committed physicalist-materialist, to the point that he was a Brouwer style intuitionist and mathematical constructivist and a staunch physicalist about the data sequences that his complexity measure was applied to. Kolmogorov's stated reason for his anti-realism about infinite sequences was not just that he was a committed Communist and dialectical materialist, but that he was specifically physicalistic about data and real mathematical entities. His commitment was not just to a form of Brouwerian intuitionism, but to physicalism about data in a similar vein to that asserted later by Rolf Landauer in the context of computer science. Kolmogorov, 1932, 6, 7;

[3]Dretske's account here is specifically about his semantic theory of information, but according to my approach all information is intrinsically semantic and non-alethic

[4]Refer to the discussion at 4.2 of Ladyman et al., 2007 for a background in difficulties with clarity about reductionism in the context of debates about scientific realism and instrumentalism and specifically in the context of Daniel Dennett's commitment to anti-reductionism and scale relativity in his thesis about real patterns (Dennett, 1991)

information: the existence of information is a sufficient condition for the existence of physical structure, and specifically *physical* structure is a necessary and sufficient condition for information. If the structure in question could not *transmit information* in the classical sense, then it is not, in fact, real. If it can, then it is real. I suggest that this is also a good - and non circular - definition of physicality: if a structure is capable of transmission of, or of participating in transmission of, information, then it is physical (see §4.4 p158.) With this definition of physicality debates about realism about causality can be deferred. I do think that transmission of information naturally necessarily requires and existentially depends upon physical cause and effect, and I will later provide a brief defeasible characterisation of how I think causation obtains using the terms of the metaphysics that I will propose [5]. The requirements for correct sufficient conditions for information have ontological implications for how real structures exist. Such structures are naturally necessarily information bearing, and the presence of information and/or information transmission (and encoding, and processing) is a sufficient condition for the obtaining of physical structure (see §7.3 p252. Refer also to Hayashi, 2017, xxxv.)

I suggest that there are four more important reasons for my physicalist-NOSR approach (NOSR):

1. (Perhaps most importantly) Physicalist reductionist NOSR accounts for and accommodates informational interpretations of ontology that preserve structure as ontologically prior to, and as an ontic existential basis for, information (I will investigate this in this chapter and Chapter 3.)

2. Physicalist reductionist NOSR provides a superior conceptual and explanatory framework for understanding necessary partialness of scientific representations due to information loss.

3. Physicalist reductionist NOSR provides a basis for development of a non-Platonistic (informational Aristotelian or in re) explanation of the nature of mathematical structures

4. Physicalist reductionist NOSR includes an avenue for explanation and characterisation of objects in the ontology as arbitrarily-bounded structured information sources.

Importantly, 1. means that information is as ubiquitous in the material universe as structure is, and this fits with longstanding (in the philosophy of information anyway) assertions about the ubiquity of information (Chalmers, 1996, 84.) In chapter 2 I will propose the radical identity thesis that it reduces (defeasibly) to the configuration of the structure(s) of the fluctuating vacuum field of quantum field theory that literally (according to our best science) exists everywhere (Cao, 2010, 205; Rugh and Zinkernagel, 2002, 1.) This thesis will assert that the real ontology of the universe is best represented by *physicalist*

[5] My suggestion will be that in accordance with scientific metaphysical methodology, causation is defeasibly a conveyance of structural change in the quantum field

reductionist non-eliminative structural realism, and that this best explains the way in which the universe is informational.

The universe, I will suggest, is the totality of veridical information sources, and is not informational at ontological bottom in some transcendentalist sense, but by virtue of being physically structural at bottom, where such structure is necessarily informational (the existence of such structure is a sufficient condition for the obtaining of information.) The meaning of 'necessarily informational' here is that it necessarily realises information, not that it is existentially based upon information realised in some other way (mathematically, computationally, or subjective-ideologically, for example.) This in turn supports my thesis that information is a truth maker, rather than a truth bearer (See, especially, Chapter 4.)

I do not think that there is a successful challenge from prospective nominalism and eliminativism about information that will undo 1., 3. and 4. I approach the challenge as follows. Begin with the idea of structure. In structural realisms the question of what kind of structures are real, and are of interest, is one of the most salient and prospectively vexing. It serves to delineate the differences between Worrall's *epistemic* structural realism, and eliminative and non-eliminative *ontic* structural realisms (and to provide a motivation for a clear formulation of the latter.)

So at minimum we are dealing with the question of whether information can exist without physical structures (whatever they are: I say selections of nonuniform regions of the quantum field, defeasibly) - or according to the terms of my approach - physical information sources (which according to the best applied statistical and complexity orientated scientific theories of information reduce to physical structures, which according to the best physics require the existence of fields.) I am claiming that it can't *in principle* on the basis of contingent findings, that its existence is established only contingently, and that it is a matter of natural necessity that it exists under certain circumstances (where necessary and sufficient conditions are met) which can be described in terms of contingent natural necessity. There may be things (or even non-things or subsistent things like fictions) to which one can apply common statistical and complexity based information measures and formulae that are not so reducible - but I contend that they don't embody real information, but instead what I will call pseudo-information (§2.3.1 p68 and §5.5 p198.) Moreover, the application of an information measure does not information make, any more than the application of any measure or formula to anything makes it what the formula was originally developed for.

1.3 A Systematic Approach to Defining Ontology

I will talk of structures rather than entities even though the ontic structural realism I endorse is non-eliminative with respect to entities (given the context of non-eliminative ontic structural realism this is somewhat trivial.) I will refer to such phenomena/systems (both unobservable and observable) as realists are realist about - and their structures - by calling them I-obtaining or I-existing: an abbreviation for 'independently informational'. Throughout this chapter and the entire thesis I will say that such structures I-exist, and this is explicitly defined as meaning the structures exist/are:

A Mind independently

B Language independently

C Formalism and Theory independently

D Computation independently

E Physical structures or are ontologically reducible to physical structures

F Subject to causal closure or

  F.1. ontologically reduce to structures that are subject to causal closure

  F.2. existentially depend upon structures that are subject to causal closure

G With causally induced configurations in accordance with

  G.1. the (altered) principle of causal closure (and PNC) limited by the primacy of physics constraint (PPC) since contemporary physics doesn't require everything to have a cause.

  G.2. ineliminability of causal pathways (ICP)

Correspondingly, I will argue on a contingent basis from inference to the best explanation, induction and with appeal to scientific usage, that information sources I-exist only, where an information source is a physical stochastic process or dynamical system (Gray, 2011a, 1, 5-6, 10-11; Gallager, 2008, 5-7; Shannon, 1998, 5.) For the moment the above is partly stipulative, but I will seek to develop/establish its contingency through the course of the chapter in keeping with the contingent scientific metaphysical purview.

C. is included because some philosophers have proposed or assumed that theories and formalisms exist Platonistically (Colyvan, 2001, Balaguer, 2001) and on similar terms to which Platonists about mathematical constructs take them to occur: that they just exist and are real in some abstract sense or Platonistic way and are only discovered - not constructed - by mathematicians and scientists. Such formalisms and theories can exist in accordance with A. and B., and can be regarded as the reductive basis of an A + B ontology.

D. is included because some physicists and scientists now take seriously either informational or computational metaphysics according to which John Wheeler's "It from Bit" thesis - or some near alternative to or revision of it is correct:

> It from bit. Otherwise put, every it—every particle, every field of force, even the space time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contexts indirectly—from the apparatus-elicited answers to yes or no questions, binary choices, bits. (Wheeler, 1989. See also Floridi, 2008a; Tegmark, 2008; Bostrom, 2009; Fredkin, 1992, 116-17.)

This kind of approach will later be analysed in terms of Steven French's idea of mathematical collapse (§7.1 p249) and what I call formalism driven conflation or formalism driven ontological descent (§3.2.2 p87 and §1.4.1 p49.) Such a metaphysics can accommodate simulation based ontologies like that inspired by Bostrom's simulation argument (Bostrom and Kulczycki, 2011.) Neither 'It From Bit' ontologies nor simulation ontologies require the agent-sustainers of idealism (but nor do they necessarily preclude them), since the former is motivated by instrumentalism and the latter can allow the simulation to be accidental or natural (i.e. not designed by any sentient or cognitive agent or any kind.) Moreover, there are panpsychists that might argue that a computational metaphysics is real in keeping with premises that say that 1. the universe and natural systems are computational (See readings in Dodig Crnkovic and Giovagnoli, 2013. See also Lloyd, 2010, 96-7; See also Zenil, 2013, 3-5; Vedral, 2010; Brooks, 2012a; Brooks, 2012b; Beavers and Harrison, 2012, 349-51; Chaitin, 2012, 280-1; Hutter, 2012, 408-12.) and 2. the existence of minds and cognition does not require the existence of mind-brains or even multiply realised neurology. Under such circumstances D. is a necessary requirement. It is interesting that from the perspective of defeasible scientific metaphysics that the addition of C. and D. has come about or become necessary because of historically relatively recent metaphysical hypotheses that are contingent upon scientific discovery especially with regards to indiscernability and qauntum indeterminacy.

G is what I will refer to for brevity as the ICP + PCC constraint. Scientists have no need of non-physical explananda that do not exist in accordance with PCC for any known empirical theory, even if statistical analysis and abstract formal constructs help with theory construction and data analysis. There is a very large literature and debate about the nature of causality and realism versus anti-realism about causality, but I will assume, in accordance with a scientific metaphysics and due to the role of causality in signal pathways in classical theories of information transmission, that there is no in-principle or ontological problem with physical causation of the kind countenanced by physicists.

There is of course an immediate potential problem for a conception of information and information transmission (via signal transmission) that requires causal inducement or causation, and causal pathways, respectively, as necessary conditions. John Bell's theorems in support of the existence of spooky action at a distance without hidden variables have been experimentally proven and re-proven, including the no loopholes versions that eliminate, as possible causes for nonlocal co-ordination, instrument influences and possible problems with random number generators for some experiments (Esfeld, 2015; Hensen et al., 2015; Bell, 2004; Aspect et al., 1981.) It would seem that these Bell-theorem experiments should perhaps count as a problem for PCC also. They do leave open the possibility that a non-physical cause is involved, since there is no positive ontic candidate available to fulfil the functional role of nonlocal causation at a distance. However, in keeping with inference to the best explanation, the no miracles argument, and the totality of results in experimental physics: neither the elimination of physical causes nor the falsity of PCC is entailed by the no-loophole versions of the Bell theorem experiments (meaningful issues regarding the nature of the physical itself notwithstanding. For further discussion see §7.3 p252.)

PCC only requires that whatever the reason for the non-locality is, it doesn't fall outside of the set of things and events that are causally closed: that require physical causes operating in accordance with natural nomic constraints. The cause, causation, and causal pathways of entanglement might be very strange, but it neither naturally nor logically necessarily follows that they are not physical and not subject to PCC (See further discussion about causation and quantum entangelment at §6.3.1 p214 and §6.6 p239.) Even if the causation involved is somehow not physical causation (a possibility which I take it that most working physicists would reject) there are counterfactual and dispositional conceptions of causation that still obey PCC. To assert otherwise without positive evidence of a substantial (involving some non-physical substance) non-physical causation would, at minimum, breach the principle of ontic parsimony, and breach it not just in terms of adding entities to the menu of existents unnecessarily with respect to explanation, but by adding entire non-natural types or categories pursuant to the same end. According to the metaphysics of information that I will formulate, causal pathways do not have to be continuous *and contiguous*: only continuous, which allows for the principle of causally induced configuration of structure to be sustained in the case of spooky action at a distance (See §6.3.1 p214. For further discussion of non-contiguous but continuous causation supporting transmission, see §3.3 p101, §7.3 p252.) ICP (the ineliminability of causal pathways) is likewise preserved according to these same considerations.

So the question to be addressed is if and when *real* information I-obtains and how, and what are the necessary and sufficient conditions are for its I-obtaining. This is not simply a word game or a-priori conceptual analysis, since there are tangible and demonstrable differences between how physically transmissible information and real information sources obtain, and the way in which (pseudo)-information associated with fictional sources obtains (See chapters 3 and 4 and §5.6 p199.)According to the metaphysics I will propose - one can transmit sequences of symbols with fictional semantic content, but the meaning of the fictions is not a necessary condition for the underlying transmission of intrinsically semantic physical information (Hartley, 1928; Shannon and Weaver, 1949.) One way to introduce this idea is to identify that there is a lot of information transmitted incidentally in any given signal (Dretske, 1981) but according to my thesis (information as the causally induced configuration of structure or CICS) - this is by way of layered *indication* (this is the basis of my solution to the symbol grounding problem.)

This highly specific characterisation of the ontological target of my enterprise is necessary because of the ontological ambiguities that appear in both the philosophy of information and ontic structural realisms. There is so much confusion at different points in the OSR literature that, as mentioned above, Steven French was led to propose that much of the field is troubled by a propensity to mathematical collapse of the ontology (French, 2014; For earlier ideas see French and Ladyman, 2003a, 41, 45.) This outcome alone places great stress on scientific realism and undoes the distinction between abstract and concrete in un unhelpful rather than constructive way. Moreover, it tends to neglect scientifically relevant and proven evidence of the efficacy of reductionism and the significant albeit problematic support for physicalism. As we will see, even Ladyman and Ross's statistical approach to OSR retains the idea that the statistical Dennettian real patterns in question are generated by I existing stochastic processes (the kinds of things that Shannon specifically called information sources) (see §3.3 p90.)

1.3.1 An Outline of a Logic of Information Dynamics with Operator Definitions

I am going to make limited use in this thesis (§7.3.2 p257 §7.4.2 p265) of a semi-formal calculus for a logic of information dynamics. In this section I will introduce the main concepts, symbols, and operators, with definitions.

Informational logics of the kind that interest philosophers of information tend to come under the heading of logics of being informed and logics of information flow (Floridi, 2011c; D'Alfonso, 2014, 318; Floridi, 2017.) Fred Dretske and Luciano Floridi are interested in the former since they are interested in naturalised epistemologies based upon naturalisation of information (although their conceptions of the nature of information are quite different.) Both make use of the concept of logical operations such as *is informed that* or *has the information that* obtaining between an agent and a situation or state of affairs, or the proposition associated with the latter:

> Previously, in chapter two, I discussed the problem whether there might be an information logic (IL), different from epistemic (EL) and doxastic logic (DL), which formalizes the relation 'a is informed that p' ($I_a p$) satisfactorily. In this chapter, I defend the view that the axiom schemata of the normal modal logic **KTB** (also known as **B** or **Br** or Brouwer's system) are well suited to model the relation of 'being informed'. After having shown that IL can be constructed as an informational reading of **KTB**, four consequences of a KTB-based IL are explored: information overload; the veridicality thesis ($I_a p \to p$); the relation between IL and EL; and the $K_p \to B_p$ principle or entailment property, according to which knowledge implies belief. (Floridi, 2011c, 224.)

Note that Floridi's conception of veridicality as expressed here is very different in its development from my own, especially since it requires that information itself (rather than representations of information sources) is alethic and a truth-bearer. As I will discuss at §5.5 p198 and §5.6 p199, veridicality according to the CICS conception of information is about the presence or absence of a real information source, as opposed to a pseudo-source. Floridi's 'is informed that' operators and relations are taken to have a basis in Dretske's conception of a signal carrying information - usually stated as the relation 'carries the information that'. The idea of using information theory to naturalise epistemology involves getting such relations as *agent S knows that P* to reduce to or be defined in terms of *agent S is informed that P*, and the latter to be supported by information dynamical relations like *signal r carries the information source s is in state F*.

Simon D'Alfonso has offered a logic of information flow which seeks to provide a characterisation of of a logical operator for the relation *A carries the information that B* in order to provide a basis in a logic of information flow for naturalised, externalist, reliabilist, informationist epistemology:

> After some work he [Dretske] ends up with the following definition: A signal r carries the information that s is F = The conditional probability of s's being F, given r (and k), is 1 (but, given k alone, ⟨1) . . . K knows that s is F = K's belief that s is F is caused (or causally sustained) by the information that s is F. . . . It is now time to introduce a symbolic vocabulary for speaking about information flow and list some of the properties which we will consider throughout our investigation. This vocabulary consists of the following:
>
> • Symbols A; B; C; D; . . . stand for information bearing structures (events/ situations/facts/signals.)
>
> • The formula $A \supset B$ stands for 'A carries the information that B'. (D'Alfonso, 2014, 318-21;)

The k is what makes Dretske's semantic conception of information naturalistic and *subjectivist*, when his conception of information is naturalistic and objectivist (information is an abstract commodity): it is the knowledge that the receiving agent has about what states are possible at the source (the receiving agent's possession of part of the source alphabet, and possibly some of the codes used for encoding the signal.) Note that the *information that* relation here again indicates that D'Alfonso takes information to be alethic or a truth-bearer, and as such his approach accommodates Floridi's veridcality formula above. Below I will present two informational 'that' operators, both of which are specifically about information based representation as defined according to my CICS conception of information. They both allow information to be non-alethic, while information based representations of information are alethic (for a full development see §5 p175.)

I am not interested in epistemic logics or the naturalisation of epistemology in this thesis: only in the naturalisation of information and its dynamics. Here I will present a prefiguration of a logic of source information *dynamics* which includes operators for information generation, encapsulation/containment, representation (information about other information), *in re* realisation, transmission, emission (natural transmission), encoding (natural and artefactual), decoding (natural and artefactual), and compression.

Instead of Floridi and D'Alfonso's predicate notations (which are purposed for reliabilist informational-epistemic logic) or D'Alfonso's information flow operator ($\supset$) I have elected to employ operator notation based upon earlier work done by myself for a describing a unified conception of biological information, which operator and its notation drew upon Paul Humphrey's physical fusion operator ($*$) for the description of emergent properties (Humphreys, 1997.) I will employ a somewhat quirky notation which involves placing denotative superscipts and subscripts on this information dynamics operator to indicate its variations and indexing respectively (more explanation of the latter below.) I have done this where it might seem more standardising and preferable to use, adapt, or extend some other operators (such as D'Alfonso's later $\supset$) because:

1. No other available operators have exactly the same semantics as those I am trying to capture, and so redeploying them with adaptation is likely to be confusing (I do not want to impose a fusion type or alternative dynamical adaptions upon D'Alfonso's more recent flow operator, as D'Alfonso's operator is very specific in its definition.)

2. Specifically, most other existing operators (including D'Alfonso's) involve a semantics according to which information has alethic value, even if they are not designed for a semantic theory or conception of information, but only about - say - Dretske's objective abstract commodity.

3. Humphrey's fusion operator is not purposed for information dynamics or flow (except insofar as the emergence of properties might be regarded as involving information dynamics - which Humphreys does not discuss) most readily accommodates the idea of both the fusion and combination of structures, and of dynamical I-obtaining operations and processes involving CICS type structure.

Regarding the motivation for considering the term 'about' to be an kind of semantic logical predicate (physico-semantic predicate) - consider that the other terms connected with information retrieval and identification in system are 'that', 'in', 'from', 'of' and 'at' (which I will denote, respectively, $*_i^\theta, *_i^\iota, *_i^\phi, *_i^\omega$, and $*_i^\alpha$ [6].) I will stipulate - on a contingent scientific metaphysical basis derived from classical statistical and algorithmic information theory and complexity theory - formal definitions for the other operators as *physico-semantic* operators. By this I mean that their semantic content is determined by reference to specific physical properties and dynamics of information encoding, representation, and transmission according to the CICS conception of information and classical and algorithmic physical theories of information.

[6] Although I will not make much use of them

Information-Dynamical Logical Operators

I will not be attempting any axioms, as I do not need nor have the scope for such development herein. The descriptions of these operators should make apparent the existence and importance of 1. capturing the variety of semantics of information and information source and transmission dynamics, without omission and 2. capturing the distinctions that arise due to differences between artefactual implementations and natural realisations of almost all process - especially encoding, decoding, and transmission:

$*_i^\iota$ Information in or *in re* (inhering in re): within source structural boundary, including in mathematical representation)

$*_i^\omega$ Information *of*: Total information of the source - within the source including its boundary.

$*_i^\alpha$ Information *at*: at the source and its immediately causally connected sources per causal continuity)

$*_i^\rho$ Information *lexically representing* or *about*:

Information in a source or CICS structure that carries causally induced configuration that's complex and involves lexical symbols encoded using artefactual source alphabets and processes of transduction or that reduce to transduction (or digitally sustained equivalents thereof) that represents information at, from, or in other sources, where the causal configuring involved some kind of artefactual encoding process. In other words, this is information configured such that it also carries or realises a structured representation of other information. The base information is a truthmaker only, but the representing structure in the information is a truthbearer: the truthbearer structure inheres in the truthmaker structure.

$*_i^\nu$ Information *naturally representing* or *about*:

Information in a source or CICS structure that carries causally induced configuration that's naturally occurring and doesn't involve non-natural lexical symbols encoded using artefactual source alphabets and processes of transduction. The base information is a truthmaker only, but the representing structure in the induced in the configuration of the CICS information is a truthbearer: the truthbearer structure inheres in the truthmaker structure (and this does not involve artefactual, lexical encoding.)

$*_i^\phi$ Information *from*: Anything specific CICS structure encoded from the source into other sources, resulting in either natural representing $*_i^\nu$ or artefactual representing $*_i^\rho$.

$*_i^\theta$ Information *that*, or the *indication* operator: semantic information encoded from the source indicating something of its configuration, nature, status, state, or dynamics/behaviour.

$*_i^\sigma$ Signal based transmission of information from one source to another:

$$S_n *_i^\sigma S_{n+1} \tag{1.1}$$

Artefactual causally sustained information transmission: Read not as S_d carries the information that B where B is some information from, at, of, or in source S_a but read instead as source of origin S_a transmits CICS information to destination or destination source S_d. The semantics do not include any conception of carrying the information *that*, since the information that operator $*_i^\sigma S^s$ is separately defined and must be applied separately. The semantics of $*_i^\sigma$ are limited to *information is transmitted* (via signal.) A naturally occurring signal constitutes emission. A telephone network transmits encoded information to a receiver, a celestial X-Ray source emits (naturally encoded) information which can arrive at a destination (which stands a receiver.) (For one description of the idea of natural encoding, see Collier, 2011.)

$*_i^\eta$ Signal based *emission* of information from one source to another:

$$S_n *_i^\eta S_{n+1} \tag{1.2}$$

Naturally occurring causally-sustained information transmission: Read not as S_d carries the information that B where B is some information from, at, of, or in source S_a but read instead as source of origin S_a emits CICS information to destination or destination source S_d. The semantics do not include any conception of carrying the information *that*, since the information that operator $*_i^\eta S^s$ is separately defined and must be applied separately. The semantics of $*_i^\sigma$ are limited to *information is transmitted* (via signal.) A naturally occurring signal constitutes emission. A telephone network transmits encoded information to a receiver, a celestial X-Ray source emits (naturally encoded) information which can arrive at a destination (which stands a receiver.) (For one description of the idea of natural encoding, see Collier, 2011.)

$\underset{i}{\Delta}$: This is a functor $\underset{i}{\Delta}$ to denote the partial information of any source structure. $\underset{i}{\Delta}(*_i^\phi S)$ Says "partial information in/of S". The $\underset{i}{\Delta}$ translates to part of the CICS. The functor plus unary $*_i^\phi$ function maps from the total set of the information in the system of sources S to a subset thereof: a subset of the causally induced configuration of their structure(s) intrinsic semantics by causal inducement that they embody.

Note that receivers and channels can be regarded as sources in the classical theory, and sources can be modelled as channels. The subscripts $_i$ are included because I want to retain the ability to enumerate and index all of the operations in a information dynamic logical expression. The reason for this is that in Shannon's theory, and in contemporary mathematical/statistical information theory, sources and channels can be chained and combined and regarded as either sources or channels. It follows that the ability to perform fusion operations on operator and functor instances is salient.

The 'information about' or lexically encoded information unary operator function ($*_i^\rho$) indicates in folk/intuitive terms that information is given to represent something: the CICS in question is also an encoding representation of some other CICS. However, this is not a clear definition. When information is said to be about something the exact meaning of this is often ambiguous. The intention can be that one is being given some kind of description, explanation, instructions, or analysis of some entity or fact. It means that a fact is being described, explained, or stated. I will stipulate (for the sake of being systematic and clear) that this operator - in formal terms - means that:

P1 a representation of some structure (including complex facts) has been encoded from alternative information sources to those comprising the fact(s) and/or structure(s) being represented.

Information $*_i^\rho$ can also be compiled on the basis of alternative sources to provide an apt representation - a model, description, and/or depiction - for the source(s)/source complex/fact(s) being represented. This can include extraction of information (CICS) from the structure be represented by encoding into representation for epistemic consumption - or not. That is the sense of 'information about' in the Dill et. al. passage in the previous section, and yet the ambiguity of English and the context seem to allow that it's also referring to information in the folding events and information from and of the folding events. Happily, these English terms have coherent parallels in contingent formal physico-semantic and mechanistic (meaning of machine mediated communication systems) information theoretic terms.

Information in ($*_i^\iota$) denotes the information contained within the structure(s) of a complex source: literally bounded within its structural boundary. Information from ($*_i^\phi$) denotes information encoded into a representation (including signal complexes) from the specific source or source complex (also a source) being represented. The representation can be naturally encoded (emissions from a pulsar or quasar) or artificially (sensor or instrument acquired data.) Information at ($*_i^\alpha$) denotes the CICS information contained within and bounded by a certain source or complex of sources (which is $*_i^\iota$) plus surrounding directly causally connected information sources at one degree of signal pathway separation.

Floridi has isolated an predicate/function associated with 'information that [it is the case that *S* obtains]' in developing a modal logic for being informed (Floridi, 2011c, 225-6.) It is an alethic and epistemic function that indicates the provision of information with a truth value. It is a different class of function. I take it that the physico-semantic functions listed can all be alternatively applied as ways in which an epistemic agent can be informed that some proposition is true, but that they are truthmakers for this kind of proposition.

1.4 Anti-Platonism about the Nature of Information

Established conceptions of information either tend to accommodate or else require platonism about information. If they do not explicitly require such platonism about information, they tend to stipulate that information is some kind of nonspecific abstracta (they do not specify how the abstracta exists) or else some kind of objective or else a subjective/epistemic probabilistic outcome, or else a measure of the latter or a value of such. These conceptions of information can be equally problematic, especially for physicalists about information. However, probabilism about information is probably worse for platonists. One straightforward problem with platonism about information is that it's broadly incompatible with the scientific conception of information according to the central applied scientific theories of importance, all of which take information to be generated by and to be existentially dependent upon physical processes and systems, or to be related to physical parameters in measured systems (that is, to actual physical magnitudes and quantities.)

Critically - there is a circularity to avoid. If information reduces to platonic structures or abstracta, or if 'the information that' is grounded in such entities, then it must still be explained how such are informational, or else how they *are* information. Importantly, the definition/conception of *abstraction* and *abstract* usually identified with studies of types (universals) and tropes is different to that involved in physics and in the applied mathematical and engineering applications of mathematical communication theory and computing. The latter involves an abstracting-out, abstracting-away, or hiding of detail or surplus structure and properties (surplus to the explanation or analysis necessary to achieve an outcome in terms of scientific and functional results) (Hayashi, 2017, xxxvi.)

It is easy to miss the central significance of, and *unavoidable* motivation for, anti-platonism about information. The primary problem with platonism about information is neither one of a failure of ontological parsimony (although I think this applies) nor of the precedence or order in which mathematical structures and descriptions and their alleged platonic existent referents are proposed. The problem is that we are interested here in the information content of platonic abstracta, and yet more specifically and importantly - the accessibility of the information. In order to be informational, they must be information sources, and they cannot possibly be information sources as they cannot participate in transmission, reception, encoding and transduction, nor be linked to any signal pathway. Armstrong's causal argument for anti-realism about platonic abstracta admits only concrete particulars, and states of affairs that reduce to them, into the ontology, since according to platonism itself platonic entities can in principle have no causal properties, thus it is impossible that we could know they exist since no causal pathway exists with which we can interact with them in any way (Armstrong, 1978 45-7; Armstrong, 1978, xiii; Armstrong, 1978a, 17-18.) This argument is thought by many philosophers to have been debunked because it misconstrues the in-principle nature of platonic abstracta (although I think this is premature and question begging.)

The response can be framed thus: that platonic abstracta are not some kind of 'ghostly' platonic forms that exist independently of corresponding concrete entities or particulars (or trope or bundle based types of various kinds) but that instead they exist in some thin ontological sense when they are referred to by formulae, descriptions, and structures in theories. Therefore their causal accessibility or lack thereof is thus irrelevant, and based on a misconstrual of their alleged nature (Colyvan, 2001, 39-40.) In other words, Armstrong burned a strawman because platonists were not making the claim about platonic existents that he ascribed (I find this to be dubious.) This response is based upon a weaker kind of platonism - one that at some points is indistinguishable to Aristotelian *in re* realism about mathematical entities which posits no platonic existents, but neither calls fictionalism into service for an explanation or characterisation of the referents of mathematical statements either.

The abovementioned response cannot work in the case of informational structures or information sources, and especially not, I suggest, if we adopt a scientific metaphysics of the kind that either Ladyman and Ross, Humphreys, or French propose. The very real problem for platonism about information sources - and therefore about information - is that our best scientific theories of communication and information tend to explicitly require either physical stochastic ergodic or else nonergodic, or even non-stochastic (chaotic systems that are quasi-deterministic are not readily categorised as random-stochastic), processes as information sources, ineliminably physical signal transmission for information transmission or movement, and physical representation (at minimum) of some kind for messages and symbols. In the scientific metaphysical sense - information does not move or exist without physical substrates. Shannon's application of frequentist statistics and his propensity to identify the information measure with a physico-statistical entropy measure, Kolmogorov's materialist constructivist-intuitionism about data sequences, and Landauer's insistence on the physical nature of data realisation *and* representation all tend to indicate as much. An indirect result of the metaphysics of information I am suggesting is that the criterion of acceptance for what is real sought by some philosophers (with respect to both realism about mathematical entities and scientific realism) is the ability to realise information and to be accessible as an information source on scientific metaphysical grounds (Colyvan, 2001, 40.)

No information is regarded as obtaining apart from such in our best scientific theories of information, including theories in physics, which latter generally defer to classical physicalist signal transmission and encoding based classical theories of information, and/or physicalist algorithmic or data based statistical and non-statistical theories. Thus, according to the primacy of physics constraint (PPC) of Ladyman and Ross, which I retain as necessary to a scientific metaphysics of information, being causal is a necessary condition for a structure or a phenomena to be informational (Ladyman et al., 2007, 190-2)

There exists a potential foil to this position from the philosophy of information: it is claimed by some philosophers that The Mathematical Theory of Communication allows that accidentally correlated and co-varying structures (and it is unclear how this can come to occur at all in any comprehensive or sufficient way in all but the most simple of systems) information transmission can be sustained without intermediate causal pathways constituting the basis of signal pathways. The only significant exception is the recent re-verification of what Einstein referred to as spooky action at a distance: nonlocal effects. There is very recent evidence in the upholding of John Bell's theorems debunking Einstein's belief (which results are again subject to defeasibility and optimistic meta-induction) in the hidden variable theorem (Hensen et al., 2015; Rudolph, 2012.) In other words, quantum non-local effects and entanglement provide a well proven example of apparent signal transmission without any discernable causal pathway (although according to one classical interpretation, the signal transmission in question cannot convey information.) I handle this significant issue economically by 1. deferring to the defeasibility component of scientific metaphysics which allows me latitude in the definition and nature of, and realism about, cause-effect relationships and causality, and 2. deference to the primacy of physics constraint and the principle of causal closure. The latter suggest, in conjunction with Later (§5.4.1 p190) I will debunk the argument from accidental correlations between structures that claims that information transmission can occur in the absence of physical, causal signal pathways serving as the basis for channels and the existential basis for co-varying.

Thus the conception of information I propose is anti-platonist. I take it that information cannot and does not exist in any transcendent platonic space or structures, nor that it can ever exist apart from spatiotemporal structures, and that even if it did it would be un-transmittable and thus inaccessible and unable to be acquired. Metaphysicians will recognise in this a direct parallel to Armstrong's causal criticism of platonism. However, this criticism of platonism about information is not vulnerable to the same rebuttals as have been directed at that argument, precisely because there is an ineliminable requirement for information to be transmitted from source to receiver in order for it to be accessed and used (For further development see §4.4 p158 p125-6.)

1.4.1 No Information in Abstract Spaces

A Shannon source, being a physical stochastic ergodic (and - according to more contemporary scientific formalisms - non-ergodic) process, is also a structure that changes over time. This is something that Platonic entities - by definition - do not do. Shannon's measure formula delivers a value based upon the probability that the source will adopt a particular possible structured state given the previous state. Thus what is measured reduces to change in physical structure of the source - its state - at points in time and over time. R. A. Fisher's information measure is also one of physically realised information. It is a metric of the quality of a statistical estimate of a physical parameter in a system given some data values. Kolmogorov's statistical measure is one of the complexity or information in the structure of a physical string of symbols - usually bit symbols representing states - considered as an object. The same reduction to physical structure goes for signals, channels, and messages in Shannon's theory. This has not stopped philosophers from regarding some of these components as existing Platonically.

The premiere presentation of the explanatory gap argument against metaphysical physicalism is probably the qualia based argument of David Chalmers. According to Chalmers qualia track phenomenal states, and qualia are evidence of the veracity of the explanatory gap argument against metaphysical physicalism. Phenomenal information is realised in or by spaces of possible phenomenal states, possible discrete experiences of phenomenal states, and possible qualia (qualities of experience) intrinsic to and determined by these possible phenomenal experiences (Chalmers, 1996, 283-4.) According to what Chalmers calls the double-aspect principle, phenomenally realised information always supervenes upon physically realised information:

> This treatment of information brings out a crucial link between the physical and the phenomenal: whenever we find an information space realised phenomenally, we find the same information space realised physically (Chalmers, 1996, 284.)

It is implied - required in fact - by Chalmer's approach that qualia must track phenomenal states per person (or vice versa.) The double aspect principle is Chalmers' supervenience physicalism applied to such information-realising possibility spaces of phenomenal states or structures: phenomenal information spaces supervene upon possible physical (neural correlate state) information spaces. Physical information is realised from or in a space of physical possibilities - possible physical states (Chalmers, 1996, 280-2.) An information space is realised by possibilia. This finding is not familiar from applied mathematical theories of information in science.

Possibility spaces of source states are familiar from Shannon's statistical model. However, Shannon's model requires that physical symbols or structures are actually physically realised by physical source states in order for information to be realised, and Shannon's possibility spaces are derived from frequency data (Hayashi, 2017.) Chalmers' construction draws upon the semantic theory of information outlined by Carnap and Bar Hillel (see chapter 5) in that it regards possibility spaces as somehow contributing real information. However, in Carnap and Bar-Hillel's case, the possibility space contributes a measure (and only a measure) of the semantic content of information, rather than the information itself (Carnap and Bar-Hillel, 1952.) Chalmers asserts that abstract spaces of possible physical brain states and of possible physically irreducible qualia not only somehow realise information apart from the existence of any source, but that a set of possible qualia constitutes information. This is a marked departure from Shannon's theory. It is a departure that makes Chalmers' conception of information not Platonistic, but possibilistic (probabilistic if one insists that the possibility space is also a probability distribution.) The double aspect-principle applied to information spaces is not enough to deliver the realisation of information.

As previously mentioned, eliminativism and pluralism about information are live metaphysical options, but in the context of Shannon's theory, real in-

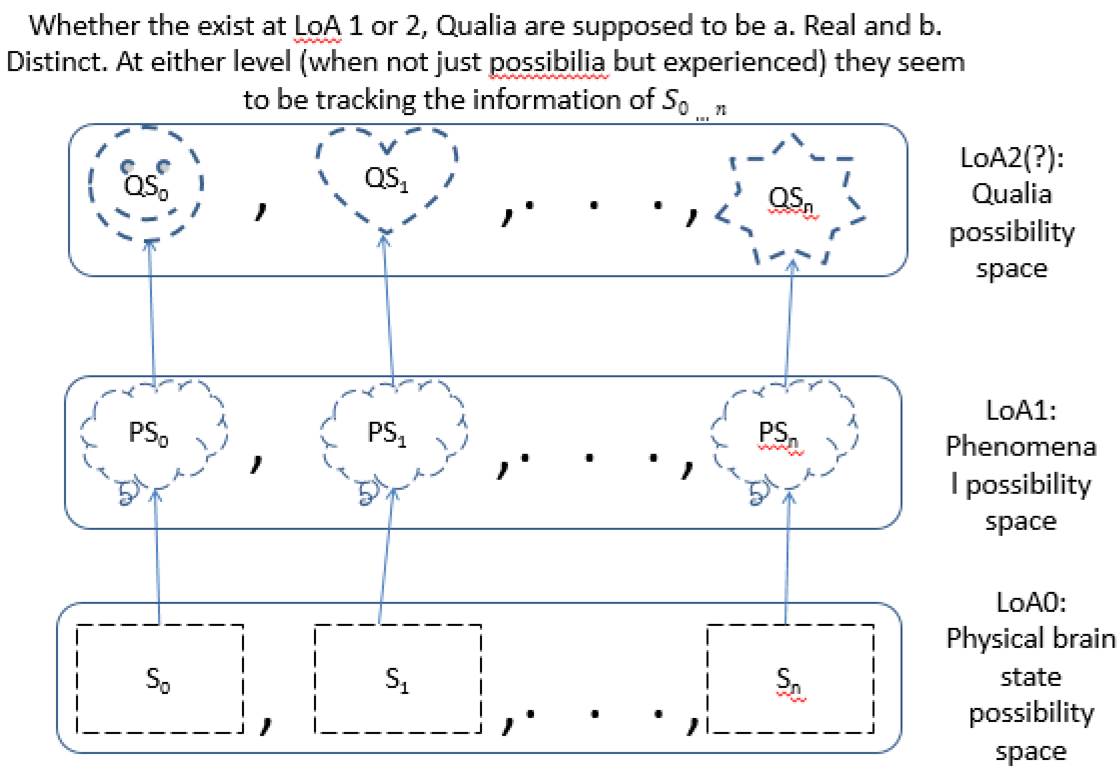

Figure 1.1: If Qualia track phenomenal states, then this has to be realised by information channels reducing to causal pathways. Accidental covariance does not constitute the transmission of information, and the statistical likelihood that the phenomenal space possibilities and quale 'states' track the complex possibilities in the phenomenal space accidentally is diminishingly small.

formation requires real/token source state changes. To avoid platonism about information, there must be physical sources or at least physically realised source state structures - not just structured abstract spaces.

Physical and phenomenal possibility spaces are abstract mathematical structures: spaces of possible physical and phenomenal states respectively. Yet even mathematical Platonists do not generally concede that possibilities are real, and so it is not even certain that possibility spaces can be abstract in the requisite sense. Chalmers also relies on the principle that information is in fact realised by structure. However, the structure is that of the abstract possibility space:

> To find information spaces realised phenomenally, we do not rely on the causal "difference that makes a difference principle"... we rely on the intrinsic qualities of experiences and the structure among them-the similarity and difference relations that they bear to each

other, and their intrinsic combinatorial structure (1996.)

According to Chalmers, it is the phenomenal information (structured possibility) space - the space of possible phenomenal states that supervenes upon the space of possible physical brain states - that results in phenomenally realised information (284-5.) However, there can be no real Shannon information from any real source or object given just an abstract possibility space information space, and nor is there Kolmogorov complexity in the absence of physical data sequences (Kolmogorov, 1968.) Shannon's theory requires - and Chalmers' double-aspect principle implies - that there must be a causal physical source structure. Even if we grant that information is intrinsic to static physical structure, and I do, Platonic abstract entities like possibility spaces regarded as Platonically or otherwise real are taken to be not only unchanging but a-causal and spatiotemporally unextended.

If we take information to be realised by information spaces as sample spaces of possible source states visa vi Shannon's theory, then physical information source structures are still ineliminable. Moreover, non-reductive supervenience of one information space upon another is similar to the idea of information transmission by accidental covariance of structures, which I will rebut at §5.4.1 p190.

Chalmers probably cannot appeal to Kolmogorov complexity of object structure, since according to that particular structure-centric conception of information the object must physically exist. Information is realised by structure as intrinsic to it. The Kolmogorov information measure is a structural complexity measure: a measure of the complexity of the structure defined as the comparative length of an encoded description of the structure of the object in some formal description language. Kolmogorov complexity is not realised by a possibility space.

The pragmatic Platonist about information may charge that this is simply all just begging the question against platonism. However:

(i) Platonic entities are normatively defined (by Platonists) to be a-causal, unchanging and non-spatiotemporal.

(ii) The $I-i$ CICS physical realist about information can provide a scientifically coherent (with respect to the main scientific theories of information) empirical and contingent story/explanation about why structures that realise information must be causal, able to change, and spatiotemporal.

(iii) The physical realist can provide a scientifically coherent story/explanation about how such structures can fulfil the functional role of information bearing and realising mathematical modelling abstracta or abstract entities by providing a physicalist and $I-i$ CICS realist definition and conception of how abstracta exist as spatiotemporal causal structures that encode information from other such structures (See Chapter 4.)

(iv) The Platonist can provide no scientifically coherent story/explanation for exactly how Platonic information bearing entities (sources) exist, nor for how exactly they might realise information, nor how exactly that information might be accessible from - or to be able to causally inform - the causal spatiotemporal structures of the material world (including the neural correlates of mental/cognitive content.)

Platonists must simply make the brute a-priori assertion that platonic entities are informational 'somehow'. Neither (ii) nor (iii) require inflating ontology beyond a scientific materialist ontology whereas it is hard to see how (iv) does not require an inflated ontology. Regarding possibility spaces as informational is arguably even more vacuous from an information theoretic perspective than platonism about information. The only possible exception might be to consider past frequency data as physical structures by considering events in terms of Minkowski spacetime, but Chalmers does not do this.

Another subtle but important complication troubles the possibilist interpretation of information. Shannon's model for continuous sources is a pragmatically discretising model: it is an approximation using the discrete source model for manageability. There is a non-trivial question about how the source coding alphabet - the set of possible source states - is determinable or ascertainable in any stable way. Different categories or ways of assigning possible states or possibilities would presumably deliver completely different possibility spaces, and all might be considered as coherent as any other. Even a specific discretising criteria might deliver varying magnitudes of possibility space for the same cognitive state space and phenomenal state space. Thus it would seem arbitrary and unjustified to limit the information space and its information to be finite.

Any assertion that (i) is wrong and that Platonic entities are somehow causal and/or spatiotemporal and/or can change *requires scientifically coherent justification and explanation on a contingent ontic basis*. Normally this requirement would be relaxed, and the Platonist could refer to a-priori Platonic abstract information or information of Platonic abstracta. This is not adequate when the ontic question is about information itself. [7].

The question is not being begged against platonism. It is just that $I - i$ CICS *in re* physical realism about information is compatible with and accounts for the scientifically normative minimum necessary and sufficient physical and causal conditions for the realisation of information sources and thus of transmissable and accessible information. platonism about information sources does not account for these conditions. Possibilism seems even less promising.

1.5 Conclusion

The objective of this Chapter was to establish a metametaphysics and systematic methodology in accordance with scientific metaphysics. I described a set of systematic criteria for such a metaphysics, which include defeasibility,

[7]Some weak versions of platonism do not assert the existence of a transcendent Platonic realm, but the explanations for how Platonic entities exist begin to converge on theories like Armstrong's immanent realist theory of universals and to become very like $I - i$ CICS realism conceptually and in terms of their ontic commitments

contingency, minimisation and elimination of a-priori conceptual analysis, and rejection of the analytic a-priori and the fecund ontology of abstracta to which such often gives rise (I will develop this further in the context of my metaphysics of information in §3 p81, §4 p137.) I prefigured an important contribution to logics of information - important because the calculus attempts to accommodate and account for information dynamics that are immutable to and ineliminable from materialist scientific discussions of information.

I then proceeded to attack one of the contemporary metaphysical mainstays of the philosophy of information: Platonism about information, and the Kantian transcendentalism that accommodates it (I do not think that Platonism about information is a necessary condition for, say, Floridi's Kantian Transcendentalism about information, as it the latter can arguably deploy other kinds of noetic spaces and is not necessarily committed to Platonism.) I made reference to the explanatory gap argument from cognitive science and the philosophy of mind, and more specifically David Chalmers' realism about qualia. Chalmers' argument from qualia against reductionism and in support of the in-principle explanatory gap is an interesting example of informationist metaphysics that arguably necessarily requires transmission of some kind in the absence of causal pathways (although the debate is complicated by the relationship between supervenience, reductionism, and non-reductive physicalism.)

Chapter 2

Towards a Metaphysics of the Nature of Information

2.1 Introduction

Humphreys has recommended that the right approach to scientific metaphysics is to regard the metaphysical postulates and observations of scientists with varying degrees of epistemic certitude or confidence depending upon the amount of epistemic and inductive risk involved in any extrapolations from known scientifically determined data (Humphreys, 2013.) In this chapter I begin to apply this principle to the philosophy of information. The term 'information' gets applied polysemously and pluralistically, and domain contextually, and yet in some important domains of the physical sciences - which scientific metaphyics suggests provide the best and most correct ontology available - the question becomes whether it's clear that there is nothing to which information refers to in the *I*-ontology corresponding to various physical formal scientific theories?". I suggest that the answer is no, and moreover that the opposite becomes apparent. This is one expression of the argument from indispensability for *naturalistic realism about I-obtaining information* that I mentioned in the introductory chapter .

The main motivation for considering a physical reductionist and scientific realist conception of information (where information is taken to be real in a similar way to physical structure in physical systems, rather than like fundamental particles or DNA) is that scientific metaphysics motivates a consideration of the apparent almost unfaltering realism about information exhibited by scientists and engineers. Scientists are notably often not capable philosophers and metaphysicians (with notable exceptions) (Humphreys, 2013, 65; Ladyman and Ross, 2013, 114-15.) Sometimes, however, special scientists are both reductionists and astute philosophers of science: see Sarkar, 2005, 236-40. Nonetheless, the scientism that motivates the kind of scientific metaphysics that I am seeking to apply to understanding the nature of what information reduces to in empirical theories arises from both the demonstrable efficacy of science for solving complex material problems, and the propensity for such theories to refer to information in what is clearly a scientific realist sense. My argument thus combines inference to the best explanation, induction, and an indispensability argument.

Regarding information, it turns out that, unsurprisingly, scientists - and especially physicists and molecular bioscientists - have always been interested in the metaphysics of information (In fact some of the most important and formative work in the discipline with respect to both classical, computational, algorithmic, and hybrid measures, and conceptions, of information.) Their discussions usually begin with opinions about, and/or semi-formal attempts to determine, whether different referents of physical theories that talk about entropy and information are identical, and/or what exactly is being measured when information is measured and how. In this chapter I continue the project of establishing the scientific metaphysical mandate, and I move towards referring to science - and especially physics in accordance with the primacy of physics constraint - to begin to establish the argument from inference to the best explanation for the nature of information in conjunction to what I have referred to as my indispensability argument for realism about information (§4 p27 H2.)

In this chapter I will also establish justification and relevance of the some of the tenets of scientific metaphysics, most prominently, defeasibility of theories and models in physics and the special sciences in accordance with the primacy of physics constraint (§2.2 p56.) I then defend my reductionist stance with reference to the dynamics of information itself, with the idea being that scientific metaphysics, especially that which respects what are understood to be physically sustained information dynamics, will tend to vindicate a stronger reductionism than has been fashionable in the philosophy of science. I will then go on to introduce the important concepts of natural encoding and the distinction between transmission and emission, and between artefactual and natural sources and source state alphabets (possibility spaces.) These concepts are important because they help progress the overall argument I am presenting in support of scientific metaphysical support for physicalist realism about information on the basis of indispensability and inference to the best explanation.

I finish the Chapter with an important set of examples from physics and molecular bioscience, making reference mostly to the discourse and theory terms of practitioners in these sciences, while introducing my own terms of reference as discussed above.

2.2 Defeasibility of Scientific Theorising

I have already introduced the idea that the defeasible nature of physics and the sciences fits with both the primacy of physics constraint and the imperatives of scientific metaphysics as I am deploying it. Adoption and incorporation (into the scientific metaphysics) of a defeasibility orientated contingent scientific metaphysics indicates that it is also not my aim to attempt anything like first philosophy. If defeasibility and revisablity in scientific theory is the norm, then a scientific metaphysics should seek to reflect this - not assume to override it or to be able to provide some logico-ontological glue or foundation of some kind that supersedes or transcends it. Defeasibility and revisability is very much the norm in QFT, for example:

> The result was, as Schwinger, among many others, argued convincingly that the concept of a fluctuating vacuum seemed to be a viable one if it was combined with the renormalization scheme developed in the late 1940s. More positively, the Casimir effect discovered in 1948 suggested that the fluctuating vacuum even had an observable effect. Only then, that is only at the end of 1940s, a firm ontological commitment to the fluctuating vacuum field was made, which signaled the maturity of the discipline. More than six decades have passed since quantum field theory matured, but as far as its ontological commitment to the vacuum field is concerned, nothing has changed (Cao, 2010, 203-8; Refer also to the discussion about the cosmological constant in Rugh and Zinkernagel, 2002, 665.) [1]

The fluctuating vacuum is of course another way of referring to what I am calling *the* (combined) quantum field and its corresponding vacuum. The process of maturing referred to above has included enormous changes in ontological commitments, and the quotation makes it clear that a change in commitment to the idea of the fluctuating vacuum was never beyond consideration. The minimal commitments of a scientific metaphysics for my purposes are:

- M1 Defeasibility of premises and claims in keeping with the defeasibility of formal sciences and their theories (Humphreys, 2013, 55-6; Cao, 2003b, 61)
- M2 Contingency or a-posteriority for premises and claims (Humphreys, 2013, 60; Ladyman and Ross, 2013, 114; Ladyman et al., 2007, 129-30, 131)
- M3 Rejection of a-priori analysis (especially ontological existence claims), including conceptual analysis (Humphreys, 2013; Ladyman and Ross, 2013 [2])
- M4 Retaining of formal logic and the various mathematical calculi indispensable to science in keeping with M1-M3 with respect to scientific ontology.

There's an important difference between Humphrey's view of defeasibility and my own. Humphreys, understandably, states that "in the absence of specific

[1] The Casimir effect is a small attractive force between uncharged conductive plates (or in other descriptions of the experiment - mirrors) that has been demonstrated to be caused by quantum field vacuum fluctuations Rugh and Zinkernagel, 2002, 6-7; Zeidler and Service, 2009, 822-3

[2] The treatment of the hybrid approach of the 'Canberra Plan' is not something that I will attempt to address in this paper.

evidence that is directly relevant to a particular scientific claim which suggests that the claim is false and the presence of specific evidence that it is true, the rational epistemic action is to accept the claim as true." (Ibid. 56.) I will qualify this with a rather significant adjustment: we should accept such claims to be defeasibly true *if they encode sufficient veridical information*, where the encoding of information from nature and from physical systems is performed by scientists and scientific apparatus and methods performing the role and function of a special kind of 'black box' encoder of information.

However, I agree with Humphreys that a more a-priori-like metaphysics - with its numerous tools including thought experiment and constrained extrapolation from established facts - sometimes unavoidably arises from open questions at the frontiers of the sciences (Humphreys, 2013, 65.) Ontological questions in the sciences are frequently posed by scientists themselves, and yet, just as a-priori ontology and metaphysics that denies or omits to acknowledge the primacy of a-posteriori science is ill-founded, it is not clear that scientific discipline without trained philosophical discipline (or at least acumen) is alone enough to do contingent a-posteriori metaphysics.

In addition to its contingent and a-posteriori character, I agree with Humphreys' assessment that scientific metaphysics is realist about the objects of scientific investigation, and that it involves a meta-inductive observation:

> It is that the methods of the physical sciences have been successful in discovering the existence and properties of a number of generally accepted entities in the physical sciences. These procedures include empirical, mathematical, and computational methods. (Humphreys, 2013, 54)

Ladyman and Ross also regard that there is little to be gained from establishing metaphysical frameworks that are not in keeping with the best scientific practice (Ladyman et al., 2007, 1.)

While there are many places that one could start, a good view of the scientific metaphysical problem domain with respect to information is available in cosmology. Humphreys reveals eloquently how the overlap between scientific information theory and metaphysics is salient to philosophical investigation:

> How can all of the relevant information needed to fix future states of the universe be encoded into a single instantaneous state? This puzzle becomes more pressing when we consider the state at the first instant of the universe. How can everything needed to guide the development of the universe for evermore be right there in a single time slice which has no history and no law-like regularities to guide its subsequent development? This is a serious difficulty for any view that insists that there can be no causal properties without an associated law, and that regularities are a necessary condition of having a law. (Humphreys, 2013, 66; Refer also to Rugh and

Zinkernagel, 2002, 664-6, 671.) [3];

Humphreys is here discussing the problem of the apparent explosion of information in the expansion of the material universe (visible within our light cone and based upon data accessible to human astronomy) in the context of doing metaphysics about nomic constraints, and determinism. This is relevant to questions about the validity of digital and informational ontology - 'it from bit' and what we might fairly call 'it from information' respectively. It is certainly salient to the enterprise of producing an informationist scientific metaphysics, as well as a scientific metaphysics of information. It is my position that *I*-existing physical structures and causality come first and are the reductive basis of information, rather than the inverse, the aforementioned *it from information* (and the closely related idea of it *as* information), as some contemporary philosophers have argued (Floridi, 2008a; Tegmark, 2008.)

In the above quoted passage, Humphreys uses the term 'encoded' to refer to the containment of information in the original finite point state of the physical universe. This is coherent according to the concept of natural encoding that I have introduced [4]. Then there is the idea that the information in the early state of the universe either might or must have somehow *guided* the development of the universe. This coheres with the concept of causally induced configuration of (signals as) sources. Yet I suggest that such ideas imply a number of assumptions about information, not all of which are contingent. They include that:

i. Information is somehow programmatic, where the property of being *programmatic* includes a kind of rule based or nomically constraining causality (I do not think Humphrey's requires teleology as a necessary component.)

ii. Information either existentially precedes physical structures and spatiotemporally structured processes, or else is somehow intrinsic to or else necessarily incidental to them (it from information, and it *as* information)

iii. There is some fixed and-or traceable relationship between information in the initial state and that in subsequent states

iv. Information has some kind of causal power (although it is not clear how this might work, except on the apparent terms of theories in physics about the early state of the universe. See also Pitalúa-García, 2013 and Al-Safi and Short, 2011)

I take it that i. - iii. are both coherent in contingent terms and align with mathematical information theory, and that iv. involves the same scepticism and uncertainty about causality and causal powers as is usually prevalent in metaphysics, with the caveat that physicists generally don't - and cannot - dispense

[3]For some research by scientists that focus on unifying information theories and the information of the expanding universe see Frieden and Petri, 2012, Ubriaco, 2009, and Frieden et al., 2011. For discussions of information in cosmology see Short and Wehner, 2010

[4]Although I confess that the causally upstream sources are what I take to be a mystery to not only myself - but all physicists

with causation. There may also be included in the above the assumption of the metaphysical doctrine of universal causality or the ontological version of the principle of sufficient reason, which has been called into question in the light of various scientific findings (Humphreys, 2013 , 55.) However, this is not clear due to the oft-noted indispensability of causation in physics.

I think that physics and mathematical information theory both allow that structure, and thus information, can be as emergent as whatever the best physics (my current chosen physics being QFT) contingently finds that they are, but with the caveat that it looks like there is no contingent or empirical evidence that physical I-obtaining structure has to be somehow conserved in the same way as natural kind energy according to the law of conservation of energy (Cao, 2010, 205-9; Swanson, 2017, 3-4.) As I have already suggested, these possibilities are not mutually exclusive with pluralism about information at different levels of explanation and abstraction.

Information might reduce to the natural equivalent of lexical sequences (and there is then a question about whether such are abstract-Platonic or always physical and how any semantic content attaches to them - i.e. the SGP), or to physical entropy (whatever that is *exactly* [5]), but without some kind of ontic overlap between the two it is hard to see how it could reduce to or involve both. The appeal of a nominal pluralism about the nature of information thus becomes apparent. My view is that there *is* an ontic overlap and moreover that there is a common ontic ground or basis for the obtaining of both sequences and entropy considered to be the basis of information. It occurs at a very basic level in the ontology, but is not so basic as to be trivial or irrelevant. There have been numerous attempts - many of them coherent and serviceable - to unify algorithmic and entropic conceptions of information (Chaitin, 1975; Zurek, 1990a; Zurek, 1990b; Zurek, 1989; Galas et al., 2010; Grünwald and Vitányi, 2003; Grünwald and Vitányi, 2003; Calude, 2009, 86-9.) Andre Kolmogorov was a rigid materialist who regarded that all data sequences were physical - a position that closely resembles the often derided brute physicalism about information (data representation) of Rolf Landauer (Landauer, 1996, Kolmogorov, 1963, Vitanyi and Li, 2009, Grünwald and Vitányi, 2003, DiVincenzo and Loss, 1998.) Kolmogorov's work is relevant because of his materialist constructivism and because he sought to develop a statistics not based upon probabilities, and yet his probability axioms are core to contemporary statistics and probability theory. Those axioms were formulated measure-theoretically by Kolmogorov and can be applied to non-probabilistic mathematics (Kolmogorov and Bharucha-Reid, 1956; Kolmogorov, 1963; Porter, 2014; Nualart, 2004, 607-8; Hájek, 2012; Shafer et al., 2001, 40-2.) The metaphysical significance of this is that, although measure theory is generally applicable to many problem domains, Kolmogorov chose it because it allowed him to restrict his theory to countable infinities only, and because the measure theoretic approach was apt to apply for physical events in a probability space considered in the context of material (empirical) random experiences (where random experience is a technical term in the theory for an

[5]Refer to the discussion below at the second quotation in §2.4 p72

empirical outcome.) Kolmogorov's notable materialist and empiricist interpretation of probabilities and mathematical entities included rejecting the existence of infinite series.

Thus, the probabilist assertion that information reduces to statistics, or else non-reductively just is statistical and/or probabilistic in nature, is on shaky ground (and I include Ladyman and Ross's statisticalist metaphysics combined with Floridi's ISR in this) if for no other reason than according to Kolmogorov - and to Ladyman and Ross themselves - there is a physical basis for algorithmically and statistically obtaining information respectively (Kolmogorov, 1932.) The probabilist about information can arguably permit contingent facts about the nature of probabilities and statistics without confusion. As I have already mentioned, however, if probabilities turn out to be something like physical propensities and therefore to supervene upon or to be existentially dependent upon stochastic processes and systems and information is statistical only, then information transitively existentially depends upon such systems also (I develop this idea to be the definition of the basis of my formulation of ontic structural informational realism OSIR at §6.2 p208.)

Under such circumstances it is doubtful that a-priori approaches - even Floridi's transcendentalist approach (Floridi, 2004b [6]) - can succeed in determining a workable metaphysics of information if for no other reason than - platonism about information not withstanding - the terms of the ontological discussion and the problem domain are largely set by physico-mathematical sciences (A transcendentalist quantum adaptation of Floridi's ISR is proposed in Bynum, 2014, 131-36.)

This physicalist and empiricist standpoint, and the rejection of the transcendentalist conception, is often denied for various reasons associated with pluralism and non-reductivism about information, using such devices as ontic neutrality - Floridi's aforementioned statement of a kind of non-physicalist multiple realisability principle for the realisation of information designed to counter the information physicalism of Rolf Landauer (Floridi, 2004a.) Yet at best it is not clear that information is not physical as Landauer asserted. More than that, there are problems with ontic neutrality, according to which information reduces to relations, where the relations are of any kind and in any kind of space (including noetic, abstract spaces conceived of numerously, and mathematical spaces) (Floridi, 2011c, 90.) At minimum, this does not seem to be easily reconcilable with classical probabilism about the nature of information: Shannon deploys Kolmogorov's axioms in Kolmogorov's empiricist and materialist spirit, which is underpinned by the important fact that Shannon's classical statistical theory of information regards only physical stochastic processes as real information sources (Shannon and Weaver, 1949.)

Perhaps, then, this discussion does point to the merits of both pluralism and eliminativism-nominalism about information. Maybe it is simply errant to attempt to attach the natural language term-label 'information' to any one thing - or type of thing - at certain levels of explanation or abstraction. Claude

[6]This is a continuation of Floridi's effort to establish a theory of semantic information)

Shannon certainly thought so:

> The word 'information' has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field. Shannon et al., 1993a

Notice that Shannon is here talking only about information theory (although, how broadly he takes that to be defined is not clear), and so this omits the multifarious attributions that had already arisen in the rest of the sciences (and the social sciences) by the 1990s. However, putting aside which term is used to label it - cosmologists, biologists, applied mathematicians and physicists alike frequently use the term to refer to something in their empirical theories: something that is associated with entropy, signaling and transmission of messages and/or signals, and with natural laws and 'instructions'.

The nature of information itself cannot be explained in terms of information, for obvious reasons, but it does not follow that it does not exist. One can only talk about it in terms of what the best scientific theories say about it (or about I-existing system dynamics taken to be information-theoretic or informational) contingently, and defer to their discussion of dynamical systems and phenomena in information-theoretic terms, and identify what in the I ontology - regardless of labelling - is thought of as information and the dynamics associated with it: the best deserver for information, to use Canberra Plan metaphysics terms. I suggest that if structure uncontroversially I-exists in the I ontology, then information does still more surely, since information can reduce to structure, but it is hard to determine what structure reduces to (although I will be proposing the radical identity thesis that it is defeasibly identical to non-uniform regions of the quantum field.)

2.3 Reductive Physicalism About Information and Informational non-eliminative ontic structural realism

Physicalism-materialism about information itself is rejected by Luciano Floridi and is largely precluded by most probabilist-subjectivist metaphysics of information. Philosophers like Fred Dretske seek naturalising formulations of the nature of information, but stop short of asserting physicalism about information itself. Mathematician Keith Devlin has a naturalising approach but doesn't foreground (and may assume but not require) physicalism-materialism (Dretske, 1981; Devlin, 1991, 84.) This is an intuitive consequence of a number of facts and conceptions, including the usefulness of theoretic and mathematical abstracta as explanatory and therefore apparently informative or information bearing (Lyon and Colyvan, 2008) and the probabilistic and popular subjectivist characterisations of semi-formal notions of information as being associated with a probabilistic surprise or *surprisal value*, or a subjective or epistemic reduction in uncertainty (it's telling that theorists often don't distinguish between subjective and objective probabilistic uncertainty, and often refer to the former when it is not necessary or supported.)

In recent history, the main framework that has been taken up by metaphysicians seeking a sound basis for scientific realism about natural systems and phenomena is ontic structural realism. Ontic structural realism originated with Worrall's epistemic variety (Worrall, 1989) and Dennett's acknowledgement of the differences in realisms about abstract entities like centers of gravity (Dennett, 1991, 29-30.) Most ontic structural realists are naturalistic philosophers - embracing what Dennett following Arthur Fine called the natural ontological attitude or NOA. Differences in naturalistic standpoint will affect the choice of ontology for ontic structural realism.

Floridi, in seeking (despite stated pluralism about the nature of information) to establish the reductive ontic basis of information for the purposes of both informational structural realism (ISR) and a theory of strongly semantic information (Floridi, 2003; Floridi, 2008a; Floridi, 2005a; Floridi, 2004b), has proposed that it obeys what he calls ontological neutrality in keeping with a rejection of Landauer's physicalism about data representation (Floridi, 2009b, 21.) Floridi's informational structural realism (ISR) is an ontologically noncommittal or neutral structural realism designed to accommodate the disparity between scientific/ontic and mathematical structural realisms since both can provide a basis for information depending upon which metaphysics is favoured by a particular information theorist or scientist. Landauer argued in terms of data *representation* necessarily requiring physical structure, which depending on the terms, principles and concepts deployed (about the nature of representation, for example) may be very different from information requiring physical structure.

The metaphysics of information that I suggest is an non-eliminative ontic structural realism that requires that both information sources and formal structures that represent them embody information on the same basis, which basis is the causally induced configuration of *I*-existing structure (CICS.) Moreover, representation can and does occur naturally and all CICS are instrinsically semantic and representational at different levels (see §7.1 p249 especially Chapter 3 [7].) Any higher level rule based or lexical semantics associated with messages still reduce to CICS - albeit on the basis of a complex of heterogeneous sources used in encoding the messages (this is my solution to the symbol grounding problem or SGP (Floridi and Taddeo, 2005 and Floridi, 2011c), which I also expand upon in chapter 3.)

However, I am also proposing a revision to non-eliminative ontic structural realism. It will involve emphasising structure as existentially prior to relations, and rendering relations (otherwise the core of most non-eliminative ontic struc-

[7] Refer also to Long, 2014

tural realism) as just elements to be picked out of structure, as opposed to determining ground or existential basis of structure (See §3.3 p90, §6.6 p242 and refer to Cao, 2010, 211-14 and French, 2006 for contextually relevant discussions.) The motivation for this inversion (which I will cover further below) in the context of scientific metaphysics is that, although our best sciences deal with what are referred to as mathematical relations, including statistical and probabilistic ones:

- Not all mathematical structures are based upon relations
- Not all science, especially hypothetico deductive motivated science, has structure that starts with relations (See again Cao, 2010, 211-12.) Often it comes from representations of natural phemonena, for example (these representations can be expressed in terms of relations, but need not be.)
- There is nothing in principle or practice wrong with asserting that relations are not the basis for structure, but just features of it or a selection of some features of it in line with the idea of partial representation.

The best support I can offer at this point for this is a visual-cum-modeling analogy. Think of the wireframe representation of a structure as a computer visualised model, or a physical wireframe for an artist's sculpture or a scientific prototype. In these cases it is at least as reasonable to state that the wireframe is regarded as an approximation of, or part of, the modelled structure only (let's assume they are all trying to model a subject or external entity to represent it, for the sake of argument to eliminate concerns about constructive elements.) The engineer, scientist, or artist has a full structure to approximate. The wireframe is an approximation by partial representation. It is a partial representation of an entire structure (see also §3.3 p101-§3.3 p109 and §4.3.1 p147.) There are relations between the different nodes (relata, components, existents, objects) in the web, but there are infinite possible spatial configurations for the web (and there is a parallel case - arguably even more so - for any abstract web like model or structure in a representation or theory.) Each of those configurations is only an approximation or partial representation of the entire structure. As the number of nodes approaches infinity, so the model approaches a full representation of the structure of that modelled. A mathematical model of the structure might be bootstrapped or start with a description of relations, but which parts or features of a partial representation one starts with would seem to have little real connection with what the objective existential basis of the structure is (See also French's reference to Murray's coverage of the Lotka-Volterra model of butterfly wings French, 2014, 102-3, **332**.)

So, as I will re-affirm at §3.3 p101 and §4.3.1 p147, whilst Cao, in summarising the tenets of non-eliminative ontic structural realism, mentions that "if we take a structure as a stable system of relations among a set of relata", I don't do so, and yet my claim is that I am still pursuing an OSR of an informational variety (Cao, 2010, 212.) Moreover, I suspect it's true that "the nature of an entity cannot be exhausted by its structural relations because an entity always possesses its natures whether or not it is, at any given moment, engaged in all relations it is capable of, which is a contingent matter" (Chakravartty, 2004) (Ibid.)

One can also approach this issue from the perspective of the mathematical fictionalist, keeping in mind that caution is required in the context of physico-mathematical QM and QFT where observables, operators, and even uncertainties are often taken to be physical or directly representative of such things as physical properties (spin etc.), physical entropy, or even physical interactions (operations.) If numbers are only fictions, then it follows that the relations described by such fictions are also fictions that are able to be deployed in a modelling setting to partially represent structure in systems. If the claim is that it is the relations being represented, then I suggest that this ontic priority is confused, since such relations in a system might be used to define a model of it, but with respect to the I-existing system, they seem to be very much only picking out a part of or a feature of the overall structure of the system, or else they may very well be relations only between constructed mathematical apparatus that emerges in the formal model during construction on a pragmatic basis or due to the deployment of a mathematical system of rules and axioms: an effective turning of the handle on the mathematical/computational machinery. This latter posit seems to be supported by the idea that more than one set of relations can be used to approximate the structure, and that any given set of relations does not fully describe the structure of a system in its totality.

I not a fictionalist, Platonist, or *in re* realist about mathematical entities and structures. I am an informationist about mathematical entities. I take this to be a new category in the philosophy of mathematics. It is more closely allied to Aristotelian *in re* or immanent realism about mathematical entities, but can accomodate the idea that mathematical abstract entities (and other entities) are only what I have called pseudo-sources. It is not my primary concern in this thesis, but informationist mathematical realism of the kind I have devised is underpinned by the scientific metaphysics of information that *is* my primary concern, and its defining features are:

- Mathematical abstracta cannot exist platonically (due to what is essentially the eliatic principle taken in conjunction with principle of natural closure and the primacy of physics constraint)
- Mathematical entities, when not fictions, are sources
- Mathematical entities that are objectively not reducible to CICS structures are pseudo-sources (§5.6 p199; §2.3.1 p68)

This analysis accommodates and makes available two possible interpretations of the nature of mathematical points: they can be source structures (physical), or pseudo-source structures (fictions.)

Most theorists take the idea that more than one set of relations can approximate, realise, or identify a structure to mean that constructive empiricist anti-realism has merit in that the I-existing ontology is ultimately inscrutable.

I suspect that this is a non-sequitur, and it is simply that infinite or near infinite selections of information can be taken from a total structure and encoded into a representation of the structure, and that noise and error in transmission and encoding is impossible to avoid. This is the very principle of abstraction (the abstracting out of surplus or bulk structure from the actual or posited structure of the I-obtaining natural phenomena or systems) that makes mathematics effective and useful. Ladyman and Ross make an indirect statement of this when, in analysing David Deutsch's metaphysics, they affirm that "Deutsch argues for the first claim just as [we] do, by invoking the fact that in scientific practice, explanations of macroscale phenomena in microphysical terms are almost never available." (Ladyman and Ross, 2013, 120.) That sometimes constructive interpolation and or extrapolation is used - including that called into service by physical posits and hypothesis like those associated with Pauli's neutrino, Einstein's gravity waves, and myriad other posits in physics including the QFT vacuum itself [8] - does not change the outcome: the model or representation so adduced or constructed is still one of many possible encodings of information selected from the I structure. It's my view that an approach according to which structure is a primitive (as opposed to structure that is based upon relations) with a physical existential reductive basis, solves several problems for the existence of properties and the distinction between I-existing and formal structure. It also helps to properly locate and situate information - or the reductive basis or ground of what scientists [9] are broadly referring to as information - when they talk about both I-ontology and formal theory ontology.

My informational non-eliminative ontic structural realism revision is obedient to Humphrey's and Ladyman and Ross's criteria for doing good naturalistic metaphysics. It minimises and even eliminates a-priori conceptual analyses (Humphreys (2013).) It is not anti-reductionist nor non-reductionist like the statistical-structuralist approach which Ladyman and Ross ultimately adopt for the basis of the nature of information and for their informational ontology (Ladyman and Ross, 2013, 612-4. See §4.3 p142; See also French's observations at French, 2014, 231, 325.) Ladyman and Ross's non-eliminative ontic structural realism becomes a kind of instrumentalism-approximating (in that science's connection with nature is limited to a statistical data based view of its structures) quasi-reductionism: they do not see statistics as reductionist especially when applied to real patterns at higher levels of abstraction, but regard that the statistics and the structure do I-obtain in the I-world.

According to Ladyman and French's earlier non-eliminative ontic structural realism (Ladyman et al., 2007) the reductive base of scientific ontology is structure that is partially isomorphic with mathematical relations in formal models, although they still defend their position regarding the nature of structure as physicalist against the similar observations to those I have just outlined but made by Cao (French and Ladyman, 2003a, 37, 40-2; Cao, 2003b, 58.) This is a similar ontological move (reduction to relational data or relations) to the alter-

[8] Neutrinos (1932-52), Schwarzchild black holes, gravity waves, frame dragging (1918, 2004-2015), heliocentrism, stomach ulcer bacteria (Helicobacter pylori), Higgs boson (1962-2012))

[9] See the previous footnote regarding the use of the term 'ground'.

native transcendentalist (Adriaans, 2010) view about information itself that has been proposed by Luciano Floridi which is central to his informational structural realism (ISR: Floridi, 2008a) and his semantic theory of information respectively. According to Floridi information reduces to ontologically neutral nonuniformities including abstract relations, and they are at in fact at the bottom of the material ontology - see §6.4 p225. It's also an ontologically similar move to the mathematical reductionism proposed by physicists such as Max Tegmark, which has been identified as mathematical collapse by French (Tegmark, 2008; French, 2014, 193-4.)

Importantly, as already mentioned, the revision of non-eliminative ontic structural realism that I propose (called OSIR or ontic structural informational realism - see §6.2 p208) is itself intended to be defeasible on the scientific realist basis suggested separately by Humphreys and Cao (Humphreys, 2013, 55-6; Cao, 2003b, 61; See also French, 2014, 324.) Ladyman and Ross emphasise the statistical and probabilistic nature of reality. This is in keeping with the understanding that statistical mechanics and statistics in general does most of the effective work in contemporary science, and forms the core - along with linear algebra - of quantum mechanics:

> The deep structure of the world is arguably not mathematical but statistical, and there is no such thing as 'purely formal statistics'. The principles of statistics are generalizations of recurrent patterns found in data; and such structuring of data is the core business of both science and its metaphysical unification. Contrary to Deutsch's claims, enlightenment optimism about the capacity for limitless expansion of knowledge is compatible with the hypothesis that the world is irreducibly and fundamentally stochastic. Among great philosophers, C.S. Peirce anticipated this hypothesis (Ladyman and Ross, 2013.)

French has also presented what is very much a naturalistic ontic structural realist scientific realist metaphysics with statistical content, but he favours the modalism that is often associated with possibility spaces in quantum systems. Guided by his aversion to the kind of ontological fecundity that arises from the many worlds interpretations of QM due to Hugh Everett and David Deutsch, which I also reject as ontologically inflationary and unjustified even in the light of the demonstrated mathematical elegance of Everett's model, French restrains his approach to the content of the structure of non-eliminative ontic structural realism (French (2014), 263-6) to incorporate *innate* modal realism (the innateness avoids concrete many worlds commitments.) Whereas Ladyman and Ross rely upon a physical mind, language, theory, and computation independent naturalised conception of statistics - statistics existing as the stochasicity of stochastic sources in nature - French instead relies upon modality as being an intrinsic mind, language, theory, and computation independent element of natural processes and systems:

> My central claim will be that we should take laws and symme-

> tries—and hence the structure of which these are features—as inherently, or primitively, modal. ... I will assume that modality is 'in' the world, in the sense that the structure of the world is modal, and the issue will be ... how to spell that out. (French, 2014, 231.)

According to my view of representing structures in formal theories, they are CICS source structures produced by a complex of encoding operation(s) which reduce to physical processes of various (and sometimes practically indeterminate kinds) being performed on information existing in external sources of various kinds in order to encode representations of the information, and that the physical encoding operations (which reduce to transduction) are performed by human agents and appropriate tools. More specifically, that the posits and models demonstrably encode veridical information from known information sources (more of this in chapters 3-5.) I suggest this is borne out by both meta-induction and inference to the best explanation with respect to the unusual success of physical posits in physico-mathematical theories historically, as well as the unusual operational effectiveness of such theories as QM and QFT. (For similar applications of the encoding concept from classical information theory, or a concept similar to it, to formal representation in physics see Ladyman et al., 2007, 208, 212-16; Rickles, 2008a , 4, 11; Rickles, 2008d, 136-8; Esfeld and Lam, 2009, 8; Ladyman and Ross (2013); Chakravartty (2004), 155; Redhead et al. (2001); Cao (2003c), 60.)

2.3.1 Brief Introduction to Naturalised Encoding and Representation, Pseudo Sources, and Pseudo Information

I will make reference to pseudo-information in this chapter (although not in any depth), and so a brief introduction to the concept (to be developed at §5.6 p199) is as follows. A real information source (existing on the physicalist and structuralist bases that I have already introduced) is the necessary existential basis of real information. A representation of such a source or sources can arise naturally by causal inducement of configuration of another structure or structures by that source. So at this point we have natural information sources and naturalised representations thereof. Such representations of the source or sources would then be veridical on a causal indicative basis: the information in the source is a truthmaker, and is not alethic, whereas the representation of the information is alethic and a potential truth bearer. Now, such representations can also be caused with an encoding step: there can be various kinds of transduction or conversion of energy involved in producing the causally downstream representation(s) from the original source(s), and such can happen according to a naturally occurring (according to natural nomic constraints) source alphabet - or set of possible source states - and an effective set of natural codes.

Astronomy is a good place to look for examples of natural sources and natural encoding of representations in their emissions as the transmission medium (the electromagnetic spectrum - and gravity waves - through the vacuum of space [10]) and the sources (spinning stars or pairs of stars respectively) have easily identifiable and isolatable macroscopic properties (Mahmoodifar and Strohmayer, 2013; Bejger, 2015; Patruno et al., 2012; Corsi and Mészáros, 2009; Corsi and Mészáros, 2009; Alford and Schwenzer, 2015 [11]. Celestial X-Ray and gravity wave sources have certain naturally constrained property limits. There are certain limits on the size and age of stars that can be pulsars, and there are certain limits - related to natural nomic constraints - upon there minimum and maximum spin rates, energy output, frequencies, and other properties all relative to their mass and density, among other things. There are limits or bounds on the amount of energy that a given size, mass and age of pulsar can emit in particle beams, for example. What these natural limits and constraints correspond to is a natural alphabet for the source: there is a finite set of allowable states that the sources can be in, and a finite set of sources configurations. To understand the latter, consider that a pulsar has dual beams/or jets which are aligned with or 'funnelled' out along its magnetic poles. This also limits the set of angles for beams relative to the axis of rotation. In pulsars where the beams are aligned with the spin axis, there is no 'lighthouse' or pulsed effect where the beam emissions intersect earth. The set of possible properties of signals/emissions from pulsars is constrained by both physical laws and geometry.

This short development of these concepts of natural encoding and representation also avails us of a glimpse at our scientific metaphysics in action. It is not known with 100% certainty what all of the limits and ratios are. Astronomers are constantly discovering errors and new data that causes them to revise the limits that they are aware of in epistemic terms:

> The new discovery, called PSR J1748-2446ad, is interesting because it spins faster than 700 Hz, which astronomers had considered a stellar speed limit. Although most pulsars should have enough self-gravity to spin as fast as 3000 times per second before they split apart, all of the previously discovered millisecond pulsars, of which there are 150 or so, spin slower than 700 Hz. That led researchers to believe that they were emitting gravitational waves – theoretical ripples in space-time – that kept their spins in check. Massive, fast-spinning objects that are not perfectly symmetrical are predicted to radiate away energy in these waves, with faster objects unleashing much more energy than slower ones. Bryan Jacoby, a pulsar expert at the National Research Council in Washington DC, US, and not part of the discovery team, says this "brick wall" effect is thought to be very effective at limiting spin rates. "If you make it spin just a little bit faster, you're emitting a lot more very strong gravitational waves," he told New Scientist. "So, the existence of this pulsar suggests the numbers [for this speed limit] aren't quite right, or that

[10] Here I simply mean outer space, rather than specifically Einstein's spacetime

[11] The Chandrasekhar limit on white dwarf mass: electron degeneracy cannot support a white dwarf heavier than 1.4 solar masses.

> something is wrong with this idea." The authors agree, saying that slowing from gravitational wave emission must become significant at spin rates higher than 700 Hz or that theorists should revise their models of neutron star crusts, which were used to arrive at the 700 Hz limit. (Hessels et al., 2006)

Although these researchers know that their data is incomplete and their predictive theories and models are partial representations and incomplete, and affected by noise and error (including signal loss that persistently obscures some data), they are also working under the assumption - valid according to the primacy of physics constraint - that they are aiming at a relatively fixed target in terms of the objectively obtaining total set of limits and properties of such X-Ray and gravity wave sources. Universal natural physical constraints - laws of physics - guarantee that such limits and properties exist even if they are not epistemically accessible to us. Scientists work with imperfect knowledge of the set of possible source configurations and states: the alphabet at the source and the set of codes for the natural encoding of emissions (transmitted messages) from the sources (Boucheron et al., 2009; Orlitsky et al., 2004.)

So the signals received by Earth based telescopes are a natural representation of the information at pulsar sources [12]. Most telescopes have transducers (which in many cases now are based on digital technology with very high sampling rates), and they encode new messages (and are themselves both elements in information channels as well as themselves sources.) These signals internal to the telescope involve human artefacts, but are also governed by natural constraints. When they are encoded from naturally occurring emissions from celestial signal sources, these also carry representations of original sources information. Now consider what happens if an astronomer generates a test sequence using the software in the telescope. The sequence is not based upon any real captured signal from any actual celestial signal source, but she could easily present it to her colleagues as such without their being suspicious (until further investigation of the claim.) Her deception involves using a non-natural representation (which nonetheless is constrained on a naturalistic basis by the physics of the equipment) the causally induced configuration of which is not due to any celestial signal source. It's essentially a fictional representation, *and the relations that represents are also fictional*, and the putative source which it represents is a pseudo-source. The information represented is pseudo-information. Correspondingly it's a pseudo-representation. As I will explain at §5.6 p199, the source that is implied to exist by the pseudo-representation is a pseudo-source, and the representation itself a virtual source.

As I will discuss later (§4.3.2 p153) with reference to black hole physics and quantum gravity - scientists are understood to make some ontological assumptions in keeping with physicalist premises and particularly the principles of causal closure and of ontological parsimony (Ladyman and Ross make ref-

[12] Rickles also refers to representations encoded from the mind, language, and theory independent ontology (Rickles, 2008a, 4.) Esfeld and Lam use this terminology non-trivially at (Esfeld and Lam, 2009, 8.)

erence to the principle of natural closure - principle of natural closure - in the same context Ladyman et al., 2007, 208, 306-8.) These assumptions can be regarded as contingent because of the principle of ontological parsimony (POP in this chapter) and in keeping with the Putnam no miracles argument, both of which were of course concerns of Worrall when he developed his original epistemic structural realism to combat pessimistic meta-induction and sustain scientific realism. That is to say - even though there are some problems with existing statements of physicalism, there is contingently no justification for being committed to the existence of informational or information bearing entities in empirical theories that are not physical: no evidence for the causally efficacious existence of non-physical or else physically irredicible information has been discovered. Abstracta in formal theories do not non-physically reducing informational entities in the ontology make.

2.3.2 Summary

In this section I have restated the need for a scientific metaphysics of information and made some minimal commitments to the doctrine (which I take to be defeasible itself), emphasising the centrality of defeasibility. I've admitted that even physicists participate in apparent a-priori speculation when they have pushed their science to the limits of discovery and detection, but that it does not follow from this that what they do is uninformed by their science: the scientific metaphysical mandate is retained. I've defended physicalist reductionist structuralism as a basis for the metaphysics of information, and restated the identification of quantum field theory as picking out the best defeasible existential basis of structure (I will pursue this further throughout the thesis §3.3 p90.) I have introduced the idea of pseudo-information and pseudo-sources, and given a brief outline of how the schema is associated with the philosophy of mathematics: I mentioned and briefly outlined *informationism* (of a very specific kind) about mathematical entities and structures. I contrasted my view of structure as an ontic primitive with the structural realist views of Ladyman and Ross (who hold a physico-statisticalist position according to which structures are relations) and French (whose position is one of realism about modality as the ontic ground of the relations constituting structure) and provided a naturalised conception of representations. We now have at least a fairly comprehensive prefiguring and statement of the specific kind of ontic structural realism that I propose should be combined defeasibly with quantum field theory using scientific metaphysical premises in order to identify - using inference to the best explanation and a specific kind of indispensability argument - the nature of information. That project will be pursued extensively in the remainder of the thesis (especially chapters 3, 4, 6, and 7.) Next however, and to close this chapter, we will refer - and defer - to some insights from physics and the special sciences that are intended to support my proposed arguments from indispensability and inference to the best explanation in the context of scientific metaphysics.

2.4 Initial Insights from Physics and Molecular Bioscience

My approach is to achieve a scientific metaphysics of information by inference to the best explanation, induction and meta-induction (induction from outcomes of induction), and by establishing an indispensability argument. We must account for references in scientific theories to dynamics such as the causal generation and transfer or transmission (often functional or critical to system properties) of signals and representations and structures between systems that I-obtain in nature, and also between those systems and representing structures in theories (Ladyman et al., 2007, 208-14, 307-12.) Something moves around which seems to involve structure but is not limited to structure, and which can be measured variously statistically and as entropy or as sequences, and it seems to be present in all sciences (refer for examples to chapter 4 and §4.3.2 p153.) Information transmission or similar dynamics (signal transmission and emission, structural transfer and replication) are the constant feature of much of science. Information theory provides ample analyses of such dynamics, and source coding theory also provides some explanatory and ontological support.

Theories of black hole physics frequently become preoccupied with discussions about, and scientific realist references to, information transmission, radiation pulses and bursts, oscillation emissions, signals and encoding, and data-compression dynamics: within quantum systems, between cosmological and celestial entities, and across event horizons (Frolov, 2014; Brádler and Adami, 2014; Hawking, 2014; Barbón, 2009; Page, 1993; Brustein and Medved, 2015; Almheiri et al., 2013; Hawking, 2005; Hawking, 1975.) Surprising findings regarding entanglement and non-locality in quantum mechanics are expressed in terms of prospective instantaneous information transmission as an outcome intrinsic to and inseparable from spooky action at a distance, although to date an interpretation due to classical information theory has led to the assertion that superluminal transmission by nonlocal effects or quantum entanglement is not possible (Walleczek and Grössing, 2016; Esfeld, 2013, 21, 23, 25; Rudolph, 2012.) However, that the idea of instantaneous and/or superluminal transmission is considered as surprising on the basis of perceived physicality of the medium and the information transmission - if not the information itself - is, I suggest, significant.

More relevantly, perhaps, quantum information theory commonly makes reference to entanglement using informational terms (which perpetuates the physicalist conception of information as existing inherent to quantum systems as discussed by DiVincenzo and loss DiVincenzo and Loss, 1998; Clifton, 2002; Bokulich and Jaeger, 2010; Bennett (2004); Norton (2005); Bennett and DiVincenzo (2000), 247. [13]) At minimum, the contingent nature of quantum information is intrinsically tied to the contingent nature of quantum probabilities, quantum statistics (especially in the context of an ontology according to

[13] Bennett and DiVincenzo directly refer to/characterise I-obtaining quantum entanglement as a quantifiable kind of information.

which the world is the nonredundant statistics as with Ladyman and Ross's OSR), and entropy [14]. Thus I suggest that information is not just some kind of poly-semantic abstractum in physics, but that it's something that is explanatory precisely because it exists as intrinsic to I-obtaining structure in the I ontology (see §4.3.2 p153.) When quantum mechanical and quantum physical theories become dependent upon formal theories of information and information measures of different kinds as explanatory in a causal and reductionist sense, then I suggest what's evidenced in scientific practice is not just scientific realist intuition limited by instrumentalist parameters, but a dependence of theory as an epistemic tool on correct representation of a real dynamical structural existent in the natural systems.

There is an information transmission concept familiar from the philosophy genetics and molecular biology due to Susan Oyama and Paul Griffiths - the parity thesis - that also reveals the way in which traditional signals and transmission channels involve more information transmission than the classical encoding-channel view of machine mediated communications requires (Shea, 2007a, Griffiths and Gray, 1994, Griffiths and Gray, 1997.) The idea is that if one inverts the relationship between channel contraints and the transmitted signal according to classical transmission theory (Shannon theory) then there's another channel and different signals. This and other adaptations of classical and complexity based information measures and theory tend to indicate that there are demonstrable common reductive bases for them, or at least that there are lower level facts about information realisation that reveal the existential basis thereof, and the basis of information realism in scientific theories.

Not only are scientists often clearly scientific realists when it comes to information, but physicists especially regard it as something physical, and assume a statement of the nature of information:

> However, much of the interest in the connection between information, i.e. "bits", and physical objects, i.e. "its", stems from the discovery that black holes have characteristics of thermodynamic systems having entropies and temperatures. This insight led to the information loss problem – what happens to the "bits" when the black hole has evaporated away due to the energy loss from Hawking radiation? [W]e speculate on a radical answer to this question using the assumption of self-similarity of quantum correction to the gravitational action and the requirement that the quantum corrected entropy be well behaved in the limit when the black hole mass goes to zero. (Singleton et al., 2014, 0-1) (See also Rovelli, 2016, 1; Esfeld and Lam, 2010, 1; Cao, 2003a, 26, 29; Müller et al., 2012, 2, 3-4, 5-6 and especially 6, 12, 15, 16; Timpson, 2005, 327-8, 329, 330.4, 331 4.1 - counter claim; Maudlin, 2013)

Here, Singleton et. al. seem to require:

[14] the real nature of which none other than Von Neumann famously said was not understood by anyone

A. Rejection of Wheeler's digital ontological thesis of 'it from bit', according to which material reality is the sum of responses to binary 'yes-no' queries made of it by scientific methods, theories, and instruments (see §1.3 p37)

B. Assumption that Shannon's classical theory is consistent with the rejection of Wheeler's 'it from bit' thesis.

According to the above passage, the bits are regarded as *in re* constituents of the black hole system, rather than being realised by the use of apparatus or instruments. An ontic structural scientific realism is implied as the correct accompanying structural realism, rather than a theory-centric epistemic structural realism. According to Shannon's theory, a bit is a unit of measure where the measure is:

$$I = -\sum plogp \tag{2.1}$$

and p is the probability of the next state of the source given the current state using Markov-chain analysis (in which the probability of the current source state is conditional upon the prior source state only.) In Shannon's classical statistical formulation, the choice of bits is driven not by a metaphysical assumption or by theory-centric premises, but by mathematical elegance (suitability, simplicity) and convenience (of base 2 logarithms) in the problem domain, and by intuition about the most appropriate measure per an intuitive concept of proportional information:

> The logarithmic measure is more convenient for various reasons: 1. **It is practically more useful. Parameters of engineering importance such as time, bandwidth, number of relays, etc., tend to vary linearly with the logarithm of the number of possibilities**. For example, adding one relay to a group doubles the number of possible states of the relays. It adds 1 to the base 2 logarithm of this number. Doubling the time roughly squares the number of possible messages, or doubles the logarithm, etc. 2. **It is nearer to our intuitive feeling as to the proper measure**. This is closely related to (1) since we intuitively measures entities by linear comparison with common standards. One feels, for example, that two punched cards should have twice the capacity of one for information storage, and two identical channels twice the capacity of one for transmitting information. 3. **It is mathematically more suitable. Many of the limiting operations are simple** in terms of the logarithm but would require clumsy restatement in terms of the number of possibilities....**The choice of a logarithmic base corresponds to the choice of a unit for measuring information. If the base 2 is used the resulting units may be called binary digits**, or more briefly bits, a word suggested by J. W. Tukey. A device with two stable positions, such as a relay or a flip-flop circuit, can store one bit of information. (Shannon and Weaver, 1949, 3-4. My emphasis.)

Thus according to the classical formalism from The Mathematical Theory of Communication, the assignation of bits is derived from the construction of the measure according to applied mathematical and intuitive premises, rather than the idea that instruments will make binary queries of natural systems. In other words, the bit very much comes from the it. Singleton et. al. above take this more seriously still - identifying the bit with the it - but not in such a way as they mathematise the ontology: the bit is a physical quantity associated with a physical structural feature in transmission.

A preliminary observation from a survey of literature on the topic of what information is in science and communications theory - and what if anything it has to do with thermodynamics and entropy - reveals that although engineers and scientists both struggle with the issues, scientists (physicists, anyway) are perhaps more concerned with metaphysical clarity than are engineers and applied mathematicians like Shannon. Although Shannon was very preoccupied with the correct designation for his measures, and with the connection with physics and statistical mechanics, he was more focused on producing a superior applied mathematical engineering solution, and this is reflected in the ambiguities - or at least dualities - in the contingent metaphysics of *The Mathematical Theory of Communication*. That said, I restate that at no point did he countenance real information being associated with anything other than physical stochastic processes.

Another place where the need for a scientific metaphysics of information becomes apparent is the probabilistic conception of information as a reduction in uncertainty ascribed to and derived from Claude Shannon's *The Mathematical Theory of Communication*, which is often referred to as the classical conception or classical formulation/notion of information. The assertion that this is the correct conception of information is faced with the problem that Shannon had some difficulty determining what he himself was referring to:

> Shannon replied: 'My greatest concern was what to call it. I thought of calling it 'information', but the word was overly used, so I decided to call it 'uncertainty' ... John von Neumann, he had a better idea. Von Neumann told me, "You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name. In the second place, and more importantly, no one knows what entropy really is, so in a debate you will always have the advantage." (McIrvine and Tribus, 1971 See also Tribus, 1988)

Moreover, although Shannon was famously pluralist about the term 'information', or at least he acknowledged its plural application in information theory, he also sought the physical basis of the nature of information:

> The formula for the amount of information is identical in form with equations representing entropy in statistical mechanics, and suggest that there may be deep-lying connections between thermodynamics and information theory. Some scientists believe that a

> proper statement of the second law of thermodynamics requires a term related to information. These connections with physics, however, do not have to be considered in the engineering and other fields. (Shannon et al., 1993b.)

So perhaps there is a common basis for realism about information between, say, physics and biology? (For the same question considered for ontic structural realism see French, 2014, 324-334.) Markedly successful efforts to unify statistical information entropy measures and mathematical representations thereof with complexity oriented representations and measures in both physics and the molecular biosciences suggest that an attempt to identify a reductive basis for both entropic and statistical-complexity conceptions of information measures and models is (See Adriaans, 2010, 45; Frieden, 2004) not without merit. This is partly an intuitive assertion, but it fits the suggested scientific metaphysical outlook.

In science successful unification of different approaches to modelling a system are often expected to verify that the same or common phenonema and microstructural dynamics are being alternatively represented (French, 2014, 333-6; Hacking, 1983; Timpson, 2005, 319, 330-1.) This assumption lies at the root of the philosophical discussion about gauge symmetries and whether all symmetries putatively represented in such theories are in fact *I* real (Rickles, 2008c; Healey, 2007.) Pieter Adriaans indicates just some of the possible and actual aspirations of unifiers of mathematical information theories and mathematical information measures:

> Possible results of such a unified theory of entropy, computation, and information could be:
>
> - A general theory about the interaction between information and computation
> - A general theory of induction
> - A general frame work to study human cognition and methodology of science
> - A theory of non-equilibrium entropy
>
> (Adriaans, 2010, 45)

In contrast to philosophers such as Fred Dretske and Luciano Floridi, who each actively seek to ground epistemology using a semantic conception of information involving (in Floridi's case at least) significant reference to a-priori analytic and logico-mathematical constructs (which in Floridi's case are intended to defer to Kantian transcendentalism to a significant degree), Adriaans separates the objectives and program of the philosophy of information and information theory from the philosophical discipline of epistemology on the grounds that "The ambition to develop such a unified theory defines a philosophical research program that is orthogonal to the classical research program of epistemology" (Adriaans, 2010, 45.) He then provides one of many definitions/statements of (the task of) the philosophy of information:

> It offers various mathematical techniques to select the right model given a set of observations. Philosophy of information studies model selection and probability. (Adriaans, 2010, 45)

Whether or not one agrees with Adriaans, his mathematicalist outlook is arguably far more in keeping with a scientific metaphysics. He stays close to the best established physico-mathematical science in his quest for a metaphysics and semantic theory of information and a characterisation of its nature.

When it comes to an a-posteriori scientific metaphysics of information, one cannot disregard the causal-realist and physicalist expectations and outlook of scientific researchers active in the field of mathematical/computational biology/molecular bioscience carrying out research into unified physico-mathematical and statistical conceptions of information for the molecular biosciences pursuant to deployment field's like oncology:

> Living systems are distinguished in nature by their ability to maintain stable, ordered states far from equilibrium. This is despite constant buffeting by thermodynamic forces that, if unopposed, will inevitably increase disorder. Cells maintain a steep transmembrane entropy gradient by continuous application of information that permits cellular components to carry out highly specific tasks that import energy and export entropy. Thus, the study of information storage, flow and utilization is critical for understanding first principles that govern the dynamics of life. Initial biological applications of information theory (IT) used Shannon's methods to measure the information content in strings of monomers such as genes, RNA, and proteins. *Recent work has used bioinformatic and dynamical systems to provide remarkable insights into the topology and dynamics of intracellular information networks. Novel applications of Fisher-, Shannon-, and Kullback–Leibler informations are promoting increased understanding of the mechanisms by which genetic information is converted to work and order.* Insights into evolution may be gained by analysis of the the fitness contributions from specific segments of genetic information as well as the optimization process in which the fitness are constrained by the substrate cost for its storage and utilization. Recent IT applications have recognized the possible role of nontraditional information storage structures including lipids and ion gradients as well as information transmission by molecular flux across cell membranes. Many fascinating challenges remain, including defining the intercellular information dynamics of multicellular organisms and the role of disordered information storage and flow in disease. (Gatenby and Frieden, 2007, 635)

Practically efficacious scientifically coherent references to transmission and transduction (information/entropy conversion) cannot be ignored here, even if Frieden is a known proponent of information-theoretic unifying and information-realist approaches. Regardless of the information measures referenced, and although it is arguably the case that, due to a lack of training in the field, as Humphreys has observed "[f]or the most part, when scientists try to do philosophy, they do it as amateurs, with noticeably poor results" (Humphreys, 2013, 65; For similar expressed views see Rickles, 2008a, Ladyman and Ross, 2013, 110) - and even though information as a concept has been treated on an eliminative ontological basis by several insightful philosophers (Levy, 2011) - a serious Canberra planner, for example, should attempt to explain "mechanisms by which genetic information is converted to work and order" in terms of a best deserver with contingent content (causal inducement of configuration per a kind of transduction?) In fact - they should more correctly be using this kind of scientific reference to *fulfil* the role of best deserver since the formal statements seem to be very much making scientific realist references.

Molecular bioscientists commonly deploy references to information transmission and transduction, particularly in association with energy exchange and conversion, and conceptions of statistically modeled physical entropy:

> The mutual information of thermodynamic coupling is incorporated into the generalized fluctuation theorem by using information theory and nonequilibrium thermodynamics. Thermodynamically coupled dissipative structures in living systems are capable of degrading more energy, and processing complex information through developmental and environmental constraints. The generalized fluctuation theorem can quantify the hysteresis observed in the amount of the irreversible work in nonequilibrium regimes in the presence of information and thermodynamic coupling. (Demirel, 2014, p. 1931.)

Mutual information measures associated with physical entropy are a basis of Shannon's classical theory. There are numerous other measures of this kind and related kinds that link statistical measures and random variables with physical outcomes (measures such as Fisher Information and Kullback-Leibler divergence) in such a way that vindicates Ladyman and Ross's metaphysical conviction that the world is 'the totality of non-redundant statistics', which I-existing statistics are irreducibly stochastic on the basis that "there is no such thing as 'purely formal statistics' ". Demirel goes on to employ standard classical formulations (together with more recent unifying adaptations) to characterise information in the context of their research matter. In so doing they retain a physicalist outlook that meshes with the kind of statisticalist-cum-physcialist view of Ladyman and Ross, but also introduce an independent abstract observer into the formal ontology:

> Information may be defined as the capacity to reduce statistical **uncertainty** in the communication of messages between a sender and a receiver . . . Consider the number of ways W in which N distinguishable entities can be assigned to M distinguishable states such that there are n_i entities in state i...In Shannon's theory, entropy represents the amount of uncertainty **one particular observer** has about the state of the system [3,5]. For a variable X

> with the $x_1, x_2, \ldots, x_N$ of its N possible states, the probability of finding X in state x_i would be p_i and Shannon's entropy H of X is $\sum_i p_i \ln p_i$ (Demirel, 2014, 1932-3)

The independent observer is not a necessary postulate. It's just explanatory metaphor. The stochastic system can simply be regarded as exhibiting an objective reduction in frequentist statistical uncertainty. The posited and obviously fictional observer is a wholly unnecessary explananda that lends weight to the impression of probabilism and platonism about information.

Demirel et. al. are applying the classical formalism to fluctuation theory to ascertain the information associated with the movement of one system/quantity in a fluid influenced by a heat bath. This is a reasonable and logical approach since such a system is representable by the Langevin equation, which represents a stochastic system by virtue of including a noise input which is a stochastic component:

> An over damped motion $x(\tau)$ of a system in contact with a heat bath and a single continuous degree of freedom can be described by the Langevin equation $\dot{x} = \mu F(x, \lambda) + \zeta$. The systematic force $F(x, \lambda)$ can arise from a conservative potential and/or be applied to the system directly as a nonconservative force, while ζ is the stochastic force, which is not affected by a time-dependent force, and μ is a positive constant. The Langevin dynamics generates trajectories $x(\tau)$ starting at x_0. For an arbitrary number of degrees of freedom, x and F become vectors. The Langevin equation is the generic equation of motion for a single fluctuating thermodynamic quantity such as the concentrations of the chemical species in the vicinity of equilibrium ... For a system in contact with a heat bath, symmetry of the probability distribution of entropy production in the steady state is known as the fluctuation theorem. Crook's fluctuation theorem compares probability distributions for the work required in the original process with that of the timereversed process. The probabilistic approach has gained broader appeal due to the advances in experimental techniques, such as atomic force microscopes and optical tweezers, for tracking and manipulation of single particles and molecules ....

So what in fact is being compared in Crook's fluctuation theorem is two casually induced spatiotemporal structures to which objective frequentist probability distributions are attached. Both the physical nature of the subsystem corresponding to the ζ term and the events associated with the frequentist distributions are physical structures with casually induced configurations.

What I hope the reader is finding to be at least plausible and a serious explanatory option, if not correct, from the exploration in this section, is that my arguments from indispensability and inference to the best explanation in support of a physicalist and structural realist naturalisation of information and representations of information are both salient and supported on a scientific metaphysical basis.

2.5 Conclusion

In this chapter I worked to further establish the scientific metaphysical approach that I am endorsing and developing, and to then segue conceptually and explanatorily into exemplars in science. I argued that although some scientific theories in physics and biology do not use the term 'information' itself, there is still ample evidence to suggest that there are core ontological concepts being deferred to in the formalisms of scientific theories. When these theories make indispensable the deployment of concepts of transmission, encoding, and processing of signals and signal borne messages or structured causal content that is functionally or otherwise efficacious and analysable, then the underlying ineleminable features of the natural systems being modelled are causal pathways and the causally induced configuration of structures.

The implication (which I am trying to move as close to an entailment as possible) of my proposed metaphysics is that the information and information-dynamics referred to in these theories (using various terms) exists externally in the world as what Floridi calls *environmental* information (Floridi, 2011c, 380-5.) That is: there is something in nature which constitutes a best deserver on a contingent basis - and terminology is not settled or is less important. This is just the kind of consideration that leads theorists to propose mathematical definitions of information. I am seeking a physicalist and reductionist characterisation of the same. Put otherwise, we should not proceed by looking for when scientists use the term 'information' as an indicator of the ontic status thereof (although we should no ignore that usage either.) We should instead identify ineliminable non-negotiable, broadly scientifically ratified (by formal scientific information theory) ontic identifiers of information systems.

Chapter 3

Introducing Field Ontic Structural Realism (FOSIR)

3.1 Introduction

I am committed to a very specific, comprehensively, and explicitly *physicalist* non-eliminative ontic structural realism, and think that this is the right ontology for situating and explaining the metaphysics of information in nature. Those familiar with various interpretations of ontic structural realism will be aware that the degree to which structure is regarded as both physical and causal, and in what ways, are both pertinent and often present difficulties for those seeking to formulate and articulate ontic structural realist ontologies and informational variations thereof (Saunders, 2003, 17; French and Ladyman, 2003b, 75-7; Esfeld and Lam, 2008, 613; French, 2014. See especially Adriaans, 2010; Floridi, 2008a and Floridi, 2011c, 347-57, 140-50., and Gillies, 2010.) Overall I am seeking to solve a host of these problems by way of the identity thesis/argument I am presenting (H2 §4 p27 and §6 p207): the structure about which ontic structural realists want to be realist is best characterised as, or recognised to be, selections of structure *in re* quantum fields and the quantum vacuum.

In this chapter I will begin to introduce one of the core arguments in my thesis: the idea of identifying structure as *in re* (to) the combined heterogeneous spacetime-permeating quantum fields of QFT - the set of all of which fields is regarded as a combined or compound heterogeneous quantum field - with the existential basis for what I will call ontic structural informational realism (OSIR), thus producing a field-ontic structural informational realism (FOSIR.) It will involve proposing an alternative scientifically inspired reductive and, importantly, *defeasible* basis (see §2 p55) for characterisation of the nature of structure: nonuniform, heterogeneous physical fields (accommodating classical fields by reduction the quantum field(s) and vacuum - see Esfeld, 1999; Esfeld and Lam, 2008, 614; Lancaster and Blundell, 2014, 1; Ladyman and Ross, 2013, 137; See also Swanson, 2017, 2-3 and §6.5 p229 p182.)

It is important to introduce this key part of my thesis here to provide a context for arguments and later discussions of other views. However, the main work of establishing the identity thesis about ontic structure inhering *in re* in bounded regions of the universal quantum field (H3) is deferred to Chapter §6 p207. A result of this approach, which is part of my central objective in determining a contingent scientific metaphysical view of the nature of information, is that I will have introduced a new proposal for the ontology of the quantum field that does not rely upon the usual posits. That proposal involves the entire combined quantum field being comprised of CICS information sources, existing as bounded regions of heterogeneous quantum fields that are themselves (dynamic CICS) sources. The boundaries could be those of a particular field excitation for a standard model particle, or some combination of different fields for different particles and/or properties.

In other words, I am introducing the identity thesis proposition/hypothesis H2 (§4 p27) to provide a field ontology *for* information via ontic structural realism, *and* as an upshot I will also have introduced a new proposal for the ontology of the universal quantum field-vacuum itself (as a set of dynamical fluctuating CICS sources), the development of which I will *not* pursue herein. As I move towards deploying a specific quantum field ontology ontic structural realism for the purposes of providing a basis for a field-ontic structural realism about information to provide an existential and reductive basis for CICS sources, I'll begin to regularly refer for support to the work of physicists who regard information as explicitly physical or conceive of it in physicalist terms and in whose theories and hypotheses information is at least as indispensable as structure [1]

In the introductory chapter I introduced the idea of an indispensability argument for the I-existence of information (§1 p16.) The indispensability argument that I am deploying works the same way as the Quine-Putnam argument in the sense that based upon scientific praxis and the encoding of representations in scientific theories. Their argument is intended to support realism about Platonic entities. My argument, however, is intended to support realism about information in nature. This based upon references to information and to informational phenomena and dynamics that are able to be modelled using one or more of the scientific information theories including, but not limited to, such things as information, signalling, signification, encoding, transmission, computation, computability, data, data representation, data transfer, patterns and pattern manipulation, programmability. In this chapter I am also going to develop an argument from inference to the best explanation intended to support the above-mentioned identity thesis H2 (4), and this argument strengthens the indispensability argument.

In chapter §1.1 p33 I dealt with the issue of Platonism and Kantian tran-

[1] Hawking, 2005, Muneyuki et al., 2010, Sagawa and Ueda, 2009, Denning and Bell, 2012, Devin, 2014, Alesci and Modesto, 2014

scendentalism about the nature of information with reference to the explanatory gap argument in cognitive science and Chalmers' argument from non-reductive realism about qualia. In this chapter (§3.4 p117) I move to deal with the proposition that nominalism about information is the best that scientific realists and information naturalisers can do - based on inference to the best explanation - to account for apparent and actual pluralism about the nature of information. This is important for at least two reasons. Firstly, because nominalism is, in many ways, a coherent position to adopt to make sense of informationist scientific discourse while being eliminativist about information as some element of the furniture of the universe. Secondly, nominalism is a preliminary basis for reasoning about existing trope bundle field ontologies for QFT, and so it threatens to impinge upon my naturalisation at the level of QFT field ontology too. I will end with specific statements of ontic structural informational realism (OSIR) and field-ontic structural informational realism (FOSIR.)

3.2 A QFT Field Ontology as the basis of OSIR

The existential indispensability argument I am developing, as I have mentioned in the introduction to this chapter and the introduction to the thesis, is intended to establish realism about natural I-existing information. It's supported by an ontic argument about the *nature* of said information. That ontic argument, which I will now pursue, is based upon inference to the best explanation and induction as constrained by the scientific metaphysical premises established earlier (§1.3 p38 and §2 p55.) It's intended to establish the best candidate for fulfilling the role of the ontic basis of I-obtaining information. The support it provides for the existential indispensability argument comes by way of the reductive conception of information so established. This conception allows information to be construed using ontic structural and dynamical terms in accordance with the CICS conception (introduced at §2.3 p62) combined with a field ontology. This broadens the vocabulary recognisable as informational and information-dynamical in the sciences and strengthens the indispensability argument for realism about naturally I-obtaining information. There is no circularity, as each argument also stands alone. In this section, through §3.3 p109 I pursue that argument, the main argument of the chapter: that the previously introduced identity between ontic structure and quantum field *in re* structure forms the basis of the most ontologically parsimonious ontology for naturalised information, most in keeping with the primacy of physics constraint and scientific metaphysics (identity thesis H2 4.)

Importantly, the inter-supporting nature of the existential indispensability argument for realism about natural I-obtaining information and the ontic argument from inference to the best explanation about the best candidate for the ontic content and nature of information is appropriately constrained. Only certain concepts are permitted to be classified as foundational or a reductive basis for information according to the ontic IBE argument. We cannot just keep claiming scientific terms arbitrarily and calling them informational, else the endeavour is rendered pointless and ineffectual. Scientific metaphysical premises constrain us to dynamics, structures, and phenomena in science that are able to be deemed informational on the basis of the terms of scientific information theory broadly construed as including statistical, algorithmic, computational (including concepts of computability), and entropic theories, and theories synthesised from these, and any reasonable reductive basis of information in these theories as adduced on the same scientific metaphysical basis. (This could be partly characterised according to Ladyman and Ross' principle of natural closure, but this is not necessary.)

There are various field ontologies that have been proposed *for* quantum field theory, where 'field ontology' refers to an ontology of quantum fields or other fields in physics (Laudisa, 2012; Kuhlmann, 2015; Kuhlmann, 2010a; Kuhlmann, 2010b.) These include process, particle, field, and trope bundle ontologies. I am using the term 'field ontology' subtly differently - to refer to a way of having an ontic structural realist ontology that is sustained by or existentially depends upon a field ontology in the first sense. This, I am arguing, is best done by way of an identity thesis (H2 at §4 p27.)

The metaphysics I propose for understanding the nature of information and the necessary and sufficient conditions for its existence is what has come to be called a field ontology (Cao, 2003c, Esfeld, 2004.) In my metaphysics of information, physicalism about structure based upon nonuniformity is retained as a necessary condition for the obtaining of the reductive basis of real information, and the medium required for real informational non-uniformities is I-obtaining fields. Such fields might be classical or the quantum field (the former reduce to the latter.) The point is that the metaphysical bottom of information as construed according to a scientific metaphysical outlook is whatever physical structure reduces to at bottom according to physics, and that currently and defeasibly (where defeasibility refers to revisability of scientific theories and knowledge based upon new information) that is fields (both classical and quantum.) Like Ladyman and Ross, my affinity for contingent scientific metaphysics includes defeasibility and statistical weight instead of impossible certainty or Cartesian and Kantian epistemic apodicticity (Ladyman and Ross, 2013, 123.)

I will not be presenting very much physics and mathematical physics: only very limited material that is enough to support the scientific metaphysical conclusions and hypotheses. In many cases I will be relying upon the expertise of philosophers of physics who are interested in non-eliminative ontic structural realism and especially classical and quantum field ontologies. A benefit of a field ontology is that in addition to structural non-uniformity, we can introduce ontic heterogeneity of I-content - or the natural kind of the field - as part of I structure and intrinsic to the realisation of information. As I will argue below, in agreement with French, when speaking of I structure of a physical system or phenomenon, the distinction between content and structure is not one of concrete versus abstract as it is between I-structure and formal abstract structure.

3.2.1 The Heterogeneous Quantum Field as The Set of All Quantum Fields

It is hardly surprising that physics, even according to a-priorist metaphysics (Wayne, 2008), is the new metaphysical discipline par excellence. Its historical development from, and epistemic and conceptual basis in, natural philosophy and mathematics, makes it the natural seat and arbiter of contemporary metaphysics. Certainly according to scientific metaphysics, metaphysical claims can only be countenanced if contingent in keeping with the primacy of physics constraint (PPC.) Nonetheless, QFT (like quantum mechanics) is one of the most notoriously difficult disciplines in physics, not only because of the usual degree of demandingness and complexity associated with its various mathematics and their calculi and algebras [2] - but precisely because there are so many of them and they are so widely interpreted with respect to their ontological commitments.

There are at least two basic problems with physics and Quantum Field Theory from the perspective of physicalism and scientific realism. One is that there are serious debates about the ontological status of the various quantum fields supporting standard model particle realisation (Esfeld, 1999; Esfeld and Lam, 2009; Redhead, 1982; Redhead, 1994; Wayne, 2008; Kuhlmann, 2010b; Kuhlmann, 2010a.) The other is that physico-mathematical operators are common in quantum physics, and they are often either identified or conflated (definitionally, conceptually, and/or ontologically) with the entities that they are being used to model and/or track (Weinberg, 1995c; Henning et al., 2016; Smolyakov and Volobuev, 2015; Willenbrock and Zhang, 2014; Smilga, 2017.) This is certainly the case with QFT since the realisation of each instance of a fundamental particle is taken to be modelled by various mathematical representations of the dynamics of variously mathematically represented fields. This lends itself heavily to both instrumentalist interpretations, and tends to result in what I have labelled formalism driven ontological descent, according to which the mathematical model and machinery becomes what is considered to be all there is to be realist about, or more severely - the actual substance of the fields and their emergent-as-low-energetic-excitation particles.

Yet it remains that matter is measured and manipulated in the laboratory, and fields are understood to be the real I-obtaining basis (somehow) of particles and matter throughout spacetime:

> **This concept of a field, an unseen entity which pervades space and time**, can be traced back to the study of gravity due to Kepler and ultimately Newton, though neither used the term and the idea of action-at-a-distance between two gravitationally attracting bodies seemed successful but nevertheless utterly mysterious. Euler's fluid dynamics got closer to the matter by considering what we

[2]Theoretical and applied physicists deploy varieties of both: consider the bra-ket notation of Paul Dirac and Richard Feynman's Feynman Diagrams for the calculi case, and consider that in QFT several different Lie algebras and techniques involving Lagrangians, Hopf algebras, Zeidler, 2006

> would now think of as a velocity field which modelled the movement of fluid at every point in space and hence its capacity to do work on a test particle imagined at some particular location. Faraday, despite (or perhaps because of) an absence of mathematical schooling, grasped intuitively the idea of an electric or magnetic field that permeates all space and time, and although he first considered this a convenient mental picture he began to become increasingly convinced that his lines of force had an independent physical existence. Maxwell codified Faraday's idea and the electromagnetic field, together with all the paraphernalia of field theory, was born. Thus in classical physics we understand that gravity is a field, electromagnetism is a field, and each can be described by a set of equations which governs their behaviour. The field can oscillate in space and time and thus wave-like excitations of the field can be found (electromagnetic waves are well-known, but gravity waves are still to be observed.) The advent of quantum mechanics removed the distinction between what had been thought of as wave-like objects and particle-like objects. **Therefore even matter itself is an excitation of a quantum field and quantum fields become the fundamental objects which describe reality**. (Lancaster and Blundell, 2014, Overture.)

In the rest of this thesis, I will frequently refer to 'the (universal) quantum field'. By this I mean the total set of all different existent quantum fields that are the basis of the emergence of all standard-particles by way of excitations of energy in the fields, along with any classified as part of the vacuum. The different kinds of quantum fields for different standard model particles are all modelled with a wide range of different algebraic mathematical apparatus. Thus they are heterogeneous in terms of their mathematical descriptions and nature (See further development at §6.3 p213.)

According to QFT, spacetime is permeated by heterogeneous standard model particle-sustaining fields, in the sense that all of the I-instances of particles that are known in the standard model come into being as energetic excitations of their respective field type instances:

> The Universe is filled with Matter. There are many different types of matter. Sometimes, physicists call these types fields and sometimes particles, the latter being elementary excitations (quanta) of the former. (Smilga, 2017)

According to QFT, these different standard model fields (identified by what is know as effective field theory, which deals with energy levels conducive to modelling excitations in fields that are manageable for particle emergence and experimental observation) all co-exist in and inhere in a universal complex of fields which are taken to have some common foundation. It is this totality of quantum fields sustaining the emerge of all standard model particles and quantum field including all quantum fields that are in vacuum or ground states, since the latter always involves the presence of energy that at any time can produce an excitation.

A standard vacuum isn't empty because no standard-model quantum field vacuum, which latter are really ground state fields, is 'empty'. Importantly, where there are no particles, there is still the (combined) quantum field (the combined various heterogeneous natural kind quantum fields) in vacuum state, because there are still quantum fields that can produce material particles (Redhead, 1994; Riek et al., 2015; Bynum, 2014, 131):

> Is empty space really empty? In the quantum field theories (QFT's) which underlie modern particle physics, the notion of empty space has been replaced with that of a vacuum state, defined to be the ground (lowest energy density) state of a collection of quantum fields. (Rugh and Zinkernagel, 2002, 1, 3-4;)

I am not asserting that there is a compound quantum field that is comprised of all other fields at all times (although I don't need to deny this either), only that the vacuum ground state of all of the standard model fields and fields for other observables, actions, and outcomes (beyond the fields for the standard model particles) can produce excitations and thus particles anywhere at any time.

3.2.2 Against Probabilism and Formalism-Driven Ontological Descent

My approach to emphasising physical structure as ontic best deserver for a basis for the naturalisation of information brings the obvious charge of neglect the central non-apodictic explanatory role of statistics in science itself. Moreover, many theories - including empirical theories - ascribe apparent informational content to apparently irreducible systems, which concept is certainly familiar from Daniel Dennett's real patterns. A reduction in statistical uncertainty - one important probabilistic conception of information - does not seem to necessarily reduce to I-obtaining structures. However, as I will explain later, this is the basis of a *measure* of information, and is therefore not a good candidate for the nature of information itself.

If statistics does somehow reduce to *in re* structure (and I think there are ways in which frequentist probabilities can be so reduced, and also propensities) then it seems statistics could be the ontic ground or basis of information - which positive thesis is what Ladyman and Ross conclude (§6.6 p234; §4.3 p142; Ladyman and Ross, 2013, 146-7.) However, Ladyman and Ross have an I physicalist and realist conception of statistics. Moreover, there are stochastic processes to be accounted for in their ontology below the non-redundant statistics: I think they have succumbed to what French calls mathematical collapse (French, 2014, 192-3) in statistical terms, with the exception that they have possible wiggle room if probabilities are just physical existents, which ontic wiggle room they do claim on what I take to be the basis of ontological parsimony. The principle of charity suggests allowing the move, but my worry is that stochasticity of a natural system or process is not its ontic ground or existential basis. Stochasticity seems to inhere in and/or be intrinsic to such processes and different aspects of their structure, but it necessarily does not seem to account for all of the structure and its content and substance, and I don't think it follows that such *in re* statistics are all that we can be scientific realists about in a natural stochastic system/process/phenomenon. My own view is that our informational and causal access is not limited to statistical structure only, and that there would still be no real information on the terms of Shannon's theory without I-obtaining physical sources, about which we can be both realist and structural realist. Shannon's theory does require that also.

Especially in physics it is apparent that fields as phenomena suffer somewhat from the same dual physico-mathematical plus mathematical characterisation as do other modeled phenomena and structures, thus again threatening to instantiate French's mathematical collapse if they are deployed in the context of NOSR as associated with structure (my project in chapters three and four.) The modelling and characterisation of fields in physics is so mathematically intensive that sometimes the term 'field' apparently refers to a mathematical construct and/or structure, sometimes it apparently primarily refers to an external physical entity or structure. It is assumed (especially by scientists who are physicalist and realist in their metaphysics) that the former presupposes the latter except where the the latter ontologically overdetermines the former as in the case of gauge symmetries (Mathur, 2009b, 7; Healey, 2007; Rickles, 2008c) [3].

French's (ontological) mathematical collapse occurs when overdetermining gauge symmetric representations push back on the I ontology and tend to produce mathematical and mathematico-informational (information reducing to mathematical abstracta and data) ontologies like that of Tegmark. I will refer to this as *formalism driven ontological descent*: the process whereby the formal representing mathematical structures become elements of the I-obtaining modelled world. French's collapse is the wholesale version of this - according to which the mathematical abstracta become themselves the entire basis of the I ontology (as with Tegmark's MUH) or else the only epistemically accessible reality, supplanting the various posited or else data derived I physical natural systems' structures.

One common definition of information derived from Shannon's theory is that it is the reduction in statistical uncertainty about the state of a source given a message from the source or else given the prior state of the source (the source could be a human speaker/utterer, and the consecutive states voicings of different phonemes or words.) To provide an idea of the scope of problem solving involved in identifying the objective nature of information (and if in fact such even exists), it is often not even clear which kind of probability is being relied upon. Shannon's theory directly suggests that if it is a reduction in uncertainty

[3] Although not infrequently physicists and philosophers of physics regard the universe as reducing to something mathematical at bottom, with varying ambiguity and clarity about what -if any - ontological commitments are being endorsed. See Tegmark, 2008, Ross et al., 2013, Ladyman et al., 2007, Floridi, 2008a

that constitutes information, then it would be a reduction in objective statistical uncertainty (corresponding to an increase in probability score) since Shannon uses frequentist probability interpretations almost exclusively (with some reference to classical probability.) However, some theorists have attributed a kind of epistemic subjective probability to Shannon by deriving semantic theories of information from Shannon's quantitative theory in which the information received by an agent is partly determined by information previously acquired from the source about the (set of) possible states that can obtain there (Dretske, 1981.)

reject that information necessarily has or involves either or both of a statistical or a subjective component. I can still significantly support the statisticalist ontic structural realism of Ladyman and Ross, according to which (in its latest version or revision) the world is the totality of nonredundant statistics. I am only interested in rejecting that information is either identical to or reduces to probabilities, likelihoods, subjective uncertainties, objective (frequentist) uncertainties, and/or what information theorists have called surprisal value. Most Shannon-inspired theories of information involve some kind of statistical measure applied to dynamic systems or processes, and/or some kind of physico-statistical outcome in such systems, as a critical or essential part of the nature of information, or else even as identical to or constituting information. Chapters one and two both include an important clarification of the conception of Claude Shannon as a physicalist, objectivist and reductive conception. The more common standard interpretation of Shannon's conception is that it is statistical or at least physico-statistical (in keeping with Shannon's reference to Boltzmann theory of entropy in a volume of gas as being the physical probabilities associated with the microstates of the system) and that Shannon takes information to be some kind of objective physico-statistical outcome or that he takes it to be identical to the value of a statistical measure of change in a dynamic process. I take this conception to be a misreading of Shannon's intent that favours an epistemic conception of information that Shannon simply does not have, or that at the very least is not a requirement for his applied mathematical theory.

Ladyman and Ross make what I think is the strongest case for a statistical ontology as the correct scientific realist scientific metaphysics, and in so doing avoid the modal innatist commitments of French's NOSR. They do so on the basis that the main challenge to their approach - necessary reducibility of stochastic laws - undermines the idea that statistics are the ontological base:

> On some conceptions of 'laws of nature', the idea of an irreducibly stochastic law is self-contradictory. As an analytic dogma, however, this can have no persuasive force for a naturalist. (Ross et al., 2013)

I do not require any deference to French's reification of modality via symmetry (or perhaps to be more generous, situation of inherent modality with symmetry laws French, 2014, 264-5.) As I have already mentioned under the head of *formalism driven ontological descent*, the pervasive confusion and often conflation of representing abstracta in formal theories with that which is taken to *I*-obtain in the world as being represented gives rise to unclarity about the exact ontic locus of what Ladyman and Ross call stochastic systems (French mentions that Suppes noticed this tendency - or something like it - in 1960 French, 2014, 334.) It is the same problem exactly, which is brought out still more clearly by the fact that Shannon's sources are both physical stochastic processes *and* the representation of stochastic processes. Ladyman and Ross are making no reference to Shannon or his communications systems model in this connexion, but the comparison is still prescient:

> A physical system, or a mathematical model of a system which produces such a sequence of symbols governed by a set of probabilities, is known as a stochastic process. (Shannon, 1998 5.)

It is not laws that are at issue, but information. Natural laws are certainly central to science, but that they are necessarily reducible is - as Ladyman and Ross have suggested - analytic dogmatism not in keeping with defeasible science. However, it is not clear that the appropriate scientific metaphysical move is then to reject reduction. Laws may reduce to information, but I suggest that although laws are informational, nomic constraints associated with them also participate in encoding and configuring of structures and thus of sources and their signals.

My contingently and scientifically derived metaphysical contention is that information does not - certainly not obviously - reduce to statistics (although it may reduce to dynamical structures that are intrinsically and even possibly physically statistical.) In fact I have rejected probabilism about information with the primary justification that in theories such as Shannon's - the statistical components are measures and where they are not Shannon defers to talk of entropy in terms of disorder in a physical source, which is the stochastic physical process that he says the statistics are used to model in the formal representation (although he certainly has a statistical mechanical conception of entropy.) I suggest that it's sources - stochastic (and in some cases non-stochastic: chaotic or deterministic) processes and dynamical natural systems at the bottom of the ontology. It's I obtaining stochastic sources that are the necessary condition for the obtaining of I stochasticity.

3.3 Ontic Structural Realism by Fields

Quantum field theory (QFT) is applied to quantum systems in special high energy relativistic circumstances where different inertial frames of reference become important and particles can annihilate and split into particle/anti-particle pairs. Correspondingly, non-relativistic quantum mechanics does not reconcile easily with the relativistic variety that gives rise to QFT. The highly utilised Schrodinger equation for describing the time evolution of a single particle quantum system in non-relativistic quantum mechanics is not suitable for modelling quantum systems in high energy relativistic settings. For one thing, the Schrodinger wave equation cannot model or capture the physical dynamics of particle annihilation and creation (Zee, 2010, 3-4; Weinberg, 1995b.)

Field theories are arguably the most important and foundational in physics. In quantum physics, quantum field theory is recognised as the best available approach to understanding and modelling multiple particle systems and especially for the study of relativistic quantum systems. There are at least three chief difficulties facing my ambition to produce a scientific physicalist reductionist ontic structural realist metaphysics of information based upon what I have called heterogeneous fields:

A. QFT, like quantum mechanics, involves the use of a lot of mathematical constructs that represent and model physical dynamics and constraints in ways that are not always straightforward in terms of the mapping from the I-system to the representation (actions, The Lagrangian, operators, and paths of evolution of a system, to name just a few. See Kuhlmann, 2010b; Swanson, 2017.)

B. A Field in classical field theory (standard electrodynamics) is often defined in terms of a *quantity* or magnitude that is evenly distributed, where the quantity is a measure or amount of something apparently undefined.

C. The relationship between QFT and classical field theory is complex, even if it is taken that quantum field theory can be extended to both different kinds of particles but also thus to explain fields at higher magnitudes and quantum systems are the basis of macroscopic systems.

In this thesis, I will refer to all of the component fields of the standard model as the quantum field or the quantum field and vacuum, which is thus heterogeneous because it is comprised of different component field types, including all of those in vacuum or ground states. Each different type of fundamental particle is an emergent unit excitation of its own field. Each standard model particle has its own field type.

QFT involves many different competing mathematical interpretations (Weinberg, 1995c; Weinberg, 1995d; Lancaster and Blundell, 2014;.) However, in its popular algebraic expressions the particles of the standard model are all taken to emerge as excitations in specific types of field. Fermions emerge as excitations of fermionic fields, likewise for bosons (bosionic), and gluons (gauge fields.) There are fields for modelling the emergence and/or obtaining of specific properties of quantum systems. Fermionic fields, bosionic fields, spinor fields, the Higgs field, tensor fields: all highlight the apparently intimate connection between maths and the material measured phenomena (For an approach involving the combination of a Lagrangian with combined derivative see Henning et al., 2016, 18-21, 40-3, 51.) However, it does not follow, from the fact that the mathematical machinations for each particle in the standard model are wrought differently, that these heterogeneous *type* fields are not able to provide an overall scientific realist and physicalist ontology in keeping with the primacy of physics constraint and with scientific metaphysics with an emphasis on the defeasibility of theories and models.They're the ontic basis of all classical electrodynamic fields in the electromagnetic spectrum and all matter.

I think that there is good reason to suggest that the variety tends to confirm a Hacking style corroboration argument: the various apparatus work because all of them are differently encoded and configured as representations and models by a fixed ontological target (albeit one that is complex.) To assume that the variety of workable representing algebraic and statistical apparatus means that the I-system is somehow ontologically completely obscure is not only unintuitive, but begins to commit the error of formalism driven ontological descent. M Theory (Membrane string theory) may well be very elegant and mathematically well suited to model otherwise apparently impenetrable problems, but it is not clear that this elegance indicates a better and more accurate representation of the I-ontology. It may well be the result of re-encoding from existing artefectual abstract mathematical artefacts rather than being like a Pauli-neutrino-posit kind of predictive outcome. Pauli's prediction involved one particle only: both the Everett Many World's interpretation of QM and string theory posit comparatively enormous ontological inflation. These quantum system and particle sustaining fields in which the excitations of energy occur in such specific ways as to produce specific outcomes which result in the existence of matter (Lancaster and Blundell, 2014, 239.)

To show why these difficulties are not fatal to my approach, it's best to point out some positive support from physics. Quantum field theory was devised to handle some of the more difficult problems with particle orientated quantum mechanics, and to solve problems with 'action at a distance'. The old laws of Coulomb and Newton involve "action at a distance". This means that the force felt by an electron (or planet) changes immediately if a distant proton (or star) moves. This situation is philosophically unsatisfactory. More importantly, it is also experimentally wrong. Beginning with classical field theory, the field theories of Maxwell and Einstein remedy the situation, with all interactions mediated in a local fashion by the field. (Tong, 2007,1-2):

> From the quantization of the electromagnetic field one is naturally led to the quantization of any classical field, the quanta of the field being particles with well-defined properties. The interactions between these particles are brought about by other fields whose quanta are other particles. For example, we can think of the interaction between electrically charged particles, such as electrons and positrons, as being brought about by the electromagnetic field or as due to an exchange of photons. *The electrons and positrons themselves can be thought of as the quanta of an electron–positron field.* An important reason for quantising such particle fields is to allow for the possibility that the number of particles changes as, for example, in the creation or annihilation of electron-positron pairs. *These and other processes of course only occur through the interactions of fields.* The solution of the equations of the quantized interacting fields is extremely difficult. (Mandl and Shaw, 2013, 16-17; Refer also to Tong, 2007, 4.)

At least since Dirac's 1927 paper *The Quantum Theory of the Emission and*

Absorption of Radiation the practice in physics is to see fields as fundamental and particles as derived concepts appearing only after quantisation of the fields. QFT provides support for the idea that if structure reduces to the quantum field and classical fields that reduce to it, then non-uniformity and heterogeneity of field natural kind(s) are intrinsic to the structure and constitute what ontic structural realists struggle to identify as content or substance of the structure about which they are realist (leading to such solutions as the statistical-physical-realist approach of Ladyman and Ross and the innate/intrinsic modality approaches of Steven French, Dean Rickles, and Michael Esfeld and Vincent Lam):

> [T]he field is primary and particles are derived concepts, appearing only after quantization. We will show how photons arise from the quantization of the electromagnetic field and how massive, charged particles such as electrons arise from the quantization of matter fields. We will learn that in order to describe the fundamental laws of Nature, we must not only introduce electron fields, but also quark fields, neutrino fields, gluon fields, W and Z-boson fields, Higgs fields and a whole slew of others. There is a field associated to each type of fundamental particle that appears in Nature. (Tong, 2007, 4.)

Ontological predictions wrought by physics and its physico-mathematical posits are surprisingly accurate. It is likely that they correspondingly have high surprisal value in the sense that this term has been used in the philosophy of information: an outcome at a source that is unlikely corresponding to a high degree of statistical uncertainty gives a greater quantitative measure of information using classical Shannon measures. $H(x) = -\sum_{i=1}^{n} p(x_i) \log p(x_i)$ is the measure. The sources state, sequence, message, symbol, or signal content corresponding with (Markov-conditional) probability $p(x_i)$. When there is a low $p(x_i)$ then $H(x)$ increases. In Dretske, 1981 Dretske adapts the Shannon measure for the information content of a single isolated discrete signal or source state. This supports the inference to the best explanation component of a defeasible metaphysics of information like OSIR that requires physical structure to I-obtain apart from and as partially represented by models encoded (in various ways) from the information in it. The successful prediction of black holes, gravity waves, frame dragging, the Higgs Boson, and the neutrino alone (§2.3 p62 p. 47) are enough to make such posits more strange than even the unusual effectiveness of mathematics in normal statistical modelling, number theory (which is surprisingly effective when coupled with digital computers) and engineering.

Combine these outcomes with Hilary Putnam's no miracles argument (NMA), according to which scientific realism is a necessary condition for avoiding explanatory recourse to entities and phenomena prospectively outside of nature and natural categories:

> '[scientific realism] is the only philosophy that does not make [the predictive success of] science a miracle'. (Putnam, 1979, 59-80. See

also Floridi, 2011c, 345. See also salient discussions at Psillos, 2009, 311-12.)

Add also the primacy of physics constraint (PPC). Together with the NMA and PPC the above outcomes suggest that there is a simple answer which is elegant - exemplified by the kind of formalism driven ontological descent adduced by Tegmark and Everett, and then there is the complex answer suggested by the idea that physics boils down to the complex (multi-rule and multi-transducer) based encoding of information from natural I phenomena (sometimes very indirectly.) I think that the complex answer is the right answer. Physicists' talk of information and information-like dynamics bottoms out in something ontologically real and regular, but it is not physical structure or causality alone.

Quantum field theory was developed in order to model quantum systems whilst taking into account special relativity: for quantum systems in high energy settings. The significance of this for the purposes of this thesis is that it provides a strong motivation for:

i) Physicalist reductionism for ontic structural realism (Cao, 2003b; Cao, 2003c; Ladyman, 2011; French and Ladyman, 2003b.)

ii) Commitment to in-principle possible non-terminating physical reduction of structures (contingent upon findings in physics.)

iii) The emphasis on nonuniform type heterogeneous fields as the basis of structure (for physicalist ontic structural realism) rather than relations, whilst retaining both relations and objects in the ontology.

QFT is the best available theory in physics for describing nature at a fundamental level using a reductionist approach. In physics the terms and elements in the models and theories and their corresponding concepts reduce because physicists take it to be the case that these explanatory, descriptive, theoretic, and conceptual reductions correspond to physical reduction in the material systems under investigation. As I have discussed above - non-eliminative ontic structural realism preserves objects in the ontology but in most versions of it objects are reduced to structures which are in turn existentially dependent upon relations. This often taken to somehow account for the move from the structures of the physical sciences to the (putatively abstract in Platonic terms) structures of mathematics.

Regarding *i*): It's physical fields that are taken to be the most fundamental of physical entities in the universe by our best physics. If I can justify - on a defeasible basis - identifying the ontic basis of structure of ontic structural realism with selections of structure from heterogeneous regions of the quantum field, then it is the I-existing quantum field that defeasibly becomes the ontologically prior primitive, with relations inhering in it *in re*. The putative scientific metaphysician's licence for regarding relations as the best candidate for the basis of structure is not then diminished. It's certainly not vacuous, and it arises from the history of the development of ontic structuralist scientific realism. Ontic structural realism does emphasise physicalist I-realism rather than theory-centric and/or percept-centric realism. Yet it is still influenced by John Worrall's theory-structure orientated epistemic structural realism, Bertrand Russell's sense-data and percept-centric indirect epistemic structural realism (where the structure is relations between percepts in the head isomorphically mapping to relations between distal and proximal causes of the percepts), and Rudolph Carnap's adoption of Ramsey sentence re-expression of logical restatements of models and equations in theories as the basis for structure (See Frigg and Votsis, 2011, 229-32.)

Relations are chosen by epistemic structural realists and ontic structural realists alike as the primary manipulable features or representations of the phenomena in theories, theory models, and in most mathematically furnished representations. However, to retain relations as the best candidate basis of structure for ontic structural realism tends towards what I will call mathematical formalism driven ontological descent (see the full development at §3.2.2 p87.) Relations are regarded as primitive in I-existing ontology *because* there is a representation of them in a theory or theory model, and the relation is not distinguished from the representation. Despite appearances, this ontic descent (similar to French's mathematical collapse) is a mistake due to misidentification of the location of the I-existing represented structures (which in the next chapter I identify with sources of information), and due to subjectivist and psychologistic projection. There is one obvious other indirect support for this assertion: Max Tegmark and Hugh Everett's explanations are completely ontologically different and mutually logically and ontologically exclusive, and even different versions of the many worlds interpretation of QM are significantly ontologically different. And this is apart from the fact that there is not even consensus between such theorists about what mathematical abstracta are and if they are even real.

QFT itself, the primacy of physics constraint, the no miracles principle, and the contingent success of physico-mathematical predictive posits in physics demonstrates why FOSIR is a good scientific metaphysics, and why favouring fields over relations as the primitive basis of structure is pertinent. If in OSR relations are between relata, and the relata are objects, and the objects are structures and therefore existentially dependent upon relations, and (according to Floridi, for example) the relations are also structure: then relation reducing non-eliminative ontic structural realism has more than one problem, and one of them seems very much to be circularity. In QFT there is available a support for my argument:

> Quantum field theory arose out of our need to describe the ephemeral nature of life...quantum field theory is needed when we confront simultaneously the two great physics innovations of the last century of the previous millenium: special relativity and quantum mechanics. It is in the peculiar confluence of special relativity and quantum mechanics that a new set of phenomena arises: Particles can be born and particles can die. (Zee, 2010, 3; See also Tong, 2007, 2)

So per the first quote in this section and the above - according to our best physics the most fundamental of objects in the material universe are not only really excitations in physical fields modelled using quantisations of fields, but they are correspondingly ephemeral. Certainly physicists use mathematical expressions of relations between quantities to model many of the properties and dynamics of such fleeting material existents: but nowhere does it seem that the relations are the basis of the fields in terms of some kind of existential dependence. The relations are picked out from the total physical information in order for physicsts to be able to model and gain a cognitive representational grasp on what might be happening, but it simply does not coherently follow that physicists regard them as the ontic reductive basis of fields and therefore of particles.

If my identity thesis (ontic structure is defeasibly identical to selections of I-existing structure inhering in the heterogeneous quantum field) holds then an ontic reduction of structure becomes available across the ontological board: representations in theories are encodings of information from I-existing structures, but are also themselves sustained by the *in re* structure of the quantum field. This is essentially Rolf Landauer's position extended to include a defeasible ontological bottom substrate for the implementation of representations: *i*) (physical reduction of ontic structure) is supported by QFT, since according to QFT, the universal quantum field and vacuum are the physical substrate in which all fleeting and persistent elementary particles in the standard model exist as emergent excitations. Regarding *iii*): What does the defeasibility mean in practical terms? Simply that if it contingently turns out that string field theorists and string theorists are instead right about how fundamental particles of the standard model exist, then string field theory would become the new ontic basis of structure for ontic structural realism (and I could still call it field-ontic structural informational realism.)

This defeasibility in the hard science, and the ability to regard ontologically different candidates for the physical substrates of material structures, might seem at odds with my whole enterprise. Doesn't all of this - especially the defeasibility component - entail that an identity thesis of the kind I am proposing is a mistake? This is only entailed if the structure of either the quantum field or its contenders (of which the string field is one) for fulfilling the best deserver role for the basis of physical ontic structure (which most proponents of OSR really want) in the ontology is asserted by physicists to be contingently (based upon the best empirical findings) non-physical. However, this is an unlikely outcome in physics-deferring scientific metaphysical terms (I've offered a succinct but important informational definition of physicality §7.3 p252 [4]) Short of such an outcome - I can have the physical *in re* selection from the total structure of heterogeneous regions of a universal quantum field for my ontic structure, or I can have the same thing from a string field.

Either way I have my causally configurable information source structure in accordance with the primacy of physics constraint, the no miracles argument,

[4] I have not developed this notion overmuch, as it brings in an entire other metaphysical (and certainly) debate. However, it's by no means a trivial offering, and my statement of it is rather well supported by my discussion in this thesis of field ontic structural informational realism.

and the principle of causal closure. Ladyman and Ross' principle of natural closure is also arguably obeyed, since there is an inter-theoretic epistemic bridging outcome according to which these hypotheses about *in re* structure and information transmission (such as that information sources are stochastic bounded regions of the heterogeneous quantum field) as a necessary condition for the obtaining of real structure and information arguably add explanatory power to the hypotheses in the field theories or information theory (or the structural realism) taken alone.

Now, regarding *ii*), I, like Simon Saunders, can therefore rely upon the real possibility that it's real, physical structures of the field *in re* kind I have been identifying - reductively all the way down (Saunders, 2003, 129.) There are lots of spooky-stuff type contingent outcomes - according to which the structure of OSR is exists *in re* in non physical spooky stuff - that could bring this undone. Although as I argue at §7.3.2 p257 , if spooky stuff of some kind is real, then according to our best science and a not unreasonable assertion of the eliatic principle in the context of the principle of causal closure and the primacy of physics constraint - such spooky stuff *in re* structure would arguably have to be causal and transmission-sustaining too, or else we'd never be able to get any information about it, and nor could it induce changes in any configuration in physical structures according to any physics we have. A less radical contingent ontological outcome that could arguably bring undone the idea of bottomless reduction to physical *in re* structures is the discrete universe hypothesis of Einstein. This is not because there would be no *in re* structure, but because if the underlying structure of the quantum field and spacetime manifold really is discretised somehow at Planck length (or some other naturally necessary interval of some kind), then it looks like something like Floridi's differences *de re* put relations back as ontologically prior: that is if one thinks that differences *de re* (remembering that Floridi's transcendentalist informational structural realism does not require physical relations as a necessary condition and/or reductive basis for the obtaining of real structure) are in fact relations of the right kind for a formulation of ontic structural realism (Floridi, 2008a, 235-7.)

However, mathematical relations are still indispensable in theories and proofs. Yet, just as there is more than one kind of abstraction, there is more than one kind of relation. Natural language terms automatically fail because they are discretising - semantically. The term 'abstract' can mean subtly different things. Something can be abstract in the sense that other details are abstracted out of or away from it, or else it can be abstract in the sense that it is abstracted *from* something (picked out of or isolated.) Similarly, something can be a relation between two field regions, or it can be a relation - somehow - between Batman's utility belt and the first quark ever to exist. The first seems to be more like Floridi's difference *de re*, perhaps inhering *in re* in a form (archaic philosophical term) or in a field (scientific ontic term of reference to a natural kind and/or phenomenon.) The latter relation is very different ontologically an semantically, and one that I analyse (§2.3.1 p68 and §5.6 p199) as being mostly pseudo-informational and fictional. My answer to how it obtains is an immanent/Aristotelian realist, reductionist, not-simple, and arguably very ontologically inelegant answer (which may or may not fail to be adequately pragmatic depending on one's conception of pragmatism, but it's as pragmatic as physics defeasibly and contingently allows it to be.) I have already characterised naturalistic codes and encoded representations (§2.3.1 p68) as themselves being causally induced configurations, where the causal inducement is done by causally upstream structures - or more specifically: source structures. Causally induced configurations of this kind are representations of the configurations - and real patterns - of the sources inducing their configurations: structures are imposed from the upstream source to the representing source. This is the common sense of understanding of naturalised representation on the basis of indication, but with emphasis on the pattern or structure that is induced. There is an undeniable element here of something like French's Viking metaphysics, since talk of the forms and en-forming (giving form to) is Aristotelian. In the case of causally induced configuration of (source) structures, we are deploying such characterisations as apt in the context of the Mathematical Theory of Communication. Remember that in Shannon's theory signals and channels can be regarded themselves as sources, and sources can be regarded as parts of a channel depending upon what is taken to be the receiver and destination of the signal and message(s.) It is the former fact that Fred Dretske deploys in identifying - in his informational naturalisation of epistemology - the source of perceptual knowledge with proximal stimuli and their resulting perceptual internal structures. It is also this set of inter-mutabilities of roles of sources and channels that avails Susan Oyama and Paul Griffiths of the now famous parity thesis, which reduces to the notion of regarding channel conditions as the signal content, and the signal and noise as the channel conditions. This interchangeable nature of the components of information transmission systems is a strong scientific metaphysical support for the idea of information transmission as the causally induced configuration of structure.

Now, I claim it to be contingent according to scientific metaphysics that relations should be taken to inhere in structures and are *not* the necessary - but only a sufficient - condition for the obtaining of structures. That is to say they are not the ontic existential basis of structures and not ontologically prior to them (see further development at §3.3 p101 and §6.6 p242.) If so then relations that inhere *in re* in either intra-source or inter-source configurations (remembering that, according to this view, sources are configured structures) are imposed by modelling and/or picked out of the total structure of the source by abstraction. The reader may well have developed the concern at this point that I have lapsed into a-priori armchair metaphysics despite my aspirations to scientific metaphysics and contingency. However, the objective of this chapter is to give a specific ontic basis to structure: that which is either identical to and/or reduces to that structure inhering *in re* in the quantum field. That is, unless the best candidate theory (with associated calculii) - in accordance with the defeasibility of scientific practice - reveals contingently that it's not the quantum field but the string field that is the substrate and substance of all structure per ontic structural realism. In which case the specific ontic basis of the substance of structure will be the structure inhering *in re* the material string field. Critically, *it does not follow from this that there is some indpendent (independent of the quantum field) abstract structure existent in the I-obtaining ontology.* There's no mediating abstracta, and there's no platonic abstracta or nominalist universal required (although the latter could reasonably be stipulated as a kind of variable reducing to a set of all field-ontic CICS structure)

This writing and my imagining is probably the first time the Batman-utility-belt-to-first-ever-quark relationship has ever been constructively picked out (this alone is prospectively philosophically interesting.) Information theoretically, it is not impossible, but extremely unlikely not to be the first time based upon the size of the available dictionary of semantic and lexical possibilities: every fictional and physical thing in the universe that natural language users who have heard of Batman's utility belt and physics have ever heard of. I am not going to engage the constructivist/objectivist debate here. Even if we take the constructivist position - the alphabet of possible source states for the fiction (possible knowings about batman's belt by possible cognitive agents) and the physics (possible first quark ideas) are enormous (depending upon whether one asks an Everettian many worlds enthusiast - the first quark could present a sizeable alphabet of its own. Transfinite perhaps?) In any case - the inelegant immanent realist FOSIR answer to how this relation obtains is that it is picked out from a very complex set of interacting CICS source structures which include those which are realised by and reduce to the physical information processing in my brain, those in the brain of whoever first imagined batman's utility belt, all of the physical and lexical encoding between that physically realised imagining and my own (textual transmission, if you like), and all of the sources in the network of sources from the who and whatever verified the existence of quarks. So it's enormous, unwieldy, and (except perhaps with a good quantum computer) probably practically impossible to catalogue, so there is arguably (obviously) an epistemic access problem. However, it does not follow from the epistemic access problem that there are not necessarily (natural necessity *and* logical necessity) physical causal transmission-capable channels that reduce to physical causal transduction and signal pathways on the basis of QFT (defeasibly), mathematical communication theory, and therefore FOSIR.

In other words, yes - I *am* saying that the relationship between Batman's utility belt and the first ever quark is sustained by a vast complex of CICS reducing pathways comprised of CICS sources that reduce to interacting heterogeneous regions of the quantum field, and that any abstracta are 'abstracted out' from this. I am aware of the conceptual heritage which I am calling into service - from Kripke's causal reference chains to informational semantics and epistemology. However, the interpretation of abstraction and my deployment of FOSIR as aspiring scientific metaphysics make my approach different.

There is admittedly no unquestioning broad consensus in physics about what it is that constitutes the foundational or fundamental stuff of the material universe, and certainly no consensus that it is necessarily fields:

> In fact, lately there has been a reaction against looking at quantum field theory as fundamental.The underlying theory might not

> be a theory of fields *or* particles, but perhaps of something quite different, like strings (Weinberg, 1995b, 1-2.)

I am not denying the basis of pessimistic metainduction - contingently false theories - but I regard that 1. it's implications have been significantly curtailed by non-eliminative ontic structural realism and 2. more significantly, the unreasonable contingent effectiveness of predictive posits in physics makes it completely moot. It is hard to see how the menagerie of successes already multiply cited - neutrinos, black holes, frame dragging, and gravity waves alone should not be regarded as having independently rendered PM moot by inference to the best explanation and induction. I defeasibly retain fields as identical to I structure here because of Weinberg's 'might'. Fields might not be structure, but they're the best candidate so far. Yet defeasibility must be retained. The true nature of the wave function itself has long been in question: is it a representation of underlying dynamical I structures, or something stranger (Ney and Albert, 2013, 2; Allori, 2013, 58.) However, there is an understanding in physics that although there might be other very distinctly different foundational entities, field theories nevertheless capture the material ontology at a very low level:

> We have learned in recent years to think of our successful quantum field theories, including quantum electrodynamics, as 'effective field theories,' low energy approximations to a deeper theory that may not even be a field theory, but something different like a string theory. (Weinberg, 1995b)

It is at this point it seems possible that something in the 'turtles all the way down' in-principle non-terminating structural reduction hypothesis of ontic structural realists could be true (Saunders, 2003; Frigg and Votsis, 2011; Esfeld, 2009b, 179-80.) However, what has emerged in physics is the idea that at the very least - not all of the turtles are of the same natural kinds, and so it's differently realised ontic *contentful* or substantial structure inhering *in re* in quantum fields all the way down. This claim about ontologically heterogeneous structure 'turtles' is based upon the current success of predictions and theories in physics. For example, according to our best current experimentally verifiable physics, the fundamental particles are excitations in the quantum field, electrons are nevertheless stubbornly spherical, and photons have a wave-particle dual nature. Thus if it is turtles all the way down, and if structure is considered to be somehow contentful and not just a mathematical projection onto the natural phenomenon: scale variability tells us that the structural turtles are most likely of different natural kinds with respect to structure itself. Furthermore, and again in accordance with the scientific metaphysical prohibition on scale invariance for both dynamics and structure: there does not seem to be a great deal of agreement about the possible specific alternative kinds of structures at different scales, and some of the structures are strange to even geometric and spatial intuitions of physicists: fields, quantised regions of fields, strings in up to 11 dimensions. If any experimental evidence for string theory appears, then that analysis will be just as relevant.

As Ladyman and Ross have observed, debates about the nature of material reality are very ancient and general metaphysical terms of reference have long since failed:

> When it comes to debates about the nature of matter in contemporary metaphysics it tends to be assumed that there are two possibilities: either there are atoms in the sense of partless particles, or there is 'gunk' in the sense of matter whose every part has proper parts (infinitely divisible matter.) This debate is essentially being conducted in the same terms as it was by the pre-Socratic philosophers among whom the atomists were represented by Democritus and the gunkists by Anaxagoras . . . Boyle, Locke, and Gassendi lined up for atomism against gunkists Descartes and Leibniz. It is preposterous that . . . contemporary metaphysicians blithely continue to suppose that the dichotomy between atoms and gunk remains relevant, and that it can be addressed a priori. Precisely what physics has taught us is that matter in the sense of extended stuff is an emergent phenomenon that has no counterpart in fundamental ontology. (Ladyman et al., 2007)

Arguably, however, in their debates about the nature and reducibility of structure and relations, ontic structural realists may be guilty of the same error but with vaguely different terms and concepts. An ontology of structure that reduces to structure can become tantamount to effective than gunkism (Ladyman et al., 2007, 44) if we do not follow the rules of scientific metaphysical conduct set for us: 1. Keep physics very close and 2. Avoid a-priori stipulation and conceptual analysis. At this point I offer the following two suggestions as scientifically ratified, or at the very least as fitting with the mandate of true scientific metaphysics. Firstly, structure is a concept that has currency in an explanatory and ontological sense, and physicists do mention the term reasonably frequently.

Above I answer the question of potentially infinite reduction of structures - which has been investigated by Simon Saunders - with a cautionary and non-committal stance (Saunders, 2003.) It does not matter so much for my purposes with the exception of determining the total information in a system. However, the idea that structure reduces to structure without any terminus in principle is an important step (scientifically supported) in establishing a scientific metaphyics of information. Heterogeneous fields are able to be the basis of intrinsic properties according to this approach. That seems to be something that is scientifically coherent and very valuable (Tong, 2007, 4.)

Not Relations, But Field Structure/CICS

My approach to ascertaining an OSR for the basis of naturalising information and information transmission will involve these steps:

i. Eliminating structure as some kind of abstracta or existent over and above the physical I-system or I-phenomena in which it inheres in re

ii. Identifying structure with/as the structure that inheres *in re* in whatever defeasible scientific theorising contingently adduces is the basis of material I-existing reality (currently the best contender, although one not without problems, is quantum field theory.)

iii. Taking the structure in ii) to be ontologically prior to, and not existentially dependent upon, relations and instead, regarding:

   a. Relations as selections of or features of information inhering in that structure

   b. Relations as a sufficient condition for the obtaining of structure, not a necessary condition

   c. Structure thus conceived of as a necessary and sufficient condition for the existence of relations

   d. Structure thus conceived of as a necessary and sufficient condition for the existence of information.

   e. Per b. and d., relations are a sufficient condition for information, but not a necessary condition.

ii. is what I am calling the identity thesis in this thesis. I will pursue its development in earnest in §6 p207.

iii.c. and iii.d. do *not* imply or entail that relations are the ontic basis of, or identical to, information. Information is the casually induced configuration of structure as conceived of in i. - iii. In other words, iii.e.

Esfeld has proposed a relation based ontology for quantum entanglement (Esfeld and Lam, 2008) and "notably quantum entanglement—poses a challenge to Lewis' Humean supervenience ... quantum physics can be taken to suggest replacing a metaphysics of intrinsic properties with a metaphysics of relations":

> A metaphysics of relations is often dismissed out of hand, for it seems to be paradoxical. It seems that (a) relations require relata, that is, things which stand in the relations, and that (b) these things have to be something in themselves, that is, must have intrinsic properties over and above the relations in which they stand. However, a metaphysics of relations merely has to reject the second part of this claim: one can maintain that (a) relations require relata, that is, things which stand in the relations, but that (not b) these things do not have any intrinsic properties that underlie the relations in which they stand. (Esfeld and Lam, 2008, 31; Esfeld and Lam, 2009, 243-4.)

The significance of Esfeld's approach is that he defers to actual (based upon the predictive power of quantum mechanics and its experimental verifiability)

I-obtaining quantum systems as a basis for formulating ontic structural realist metaphysical premises. i. - iii. above (which I will spend this and the next chapter developing, as well as chapter 6.) constitute a similar but broader and stronger move to make the I world the locus of ontic structural realism, but less elegantly (more brutely [5]) and without any dependence upon supervenience principles.

I am proposing an non-eliminative ontic structural realism according to which - not just laws and symmetries - but relations and relata are both *features* of structure, and not its basis. This is also suggested by holism about the quantum world:

> Quantum entanglement [according to which spatiotemporally separated systems have interdependent properties], by contrast, suggests a sort of holism: instead of the intrinsic properties of the parts fixing the relations among them and thus the state of the whole, only the state of the whole fixes the relations among the parts (Esfeld and Lam, 2009, 246.)

In fact Esfeld has an instrumentalist view about the quantum field, and is *not* an I-realist or scientific realist about it exiting in a physical sense somehow (See §6.3 p213.) Ladyman and Ross attack (rightly) Theodore Sider's a-priori approach to metaphyics as not naturalised visa vi scientific motivation:

> Certainly, it seems that any satisfactory ontology will have to include self-individuating elements, the only question being which entities have this status-space-time points, bare particulars, tropes, and individual substances all being among the possible candidates' (93.) Certainly? None of these 'obvious' elements of reality (including pseudoscientific 'space-time points') are known to either everyday intuition or science. (Ladyman et al., 2007, 14-15.)

However, do webs of relations and relata and nodes fair any better in terms of realism about the scientific image? I think that there is good reason to think that they do not, including some of the moves made by ontic structural realists to explain them and/or situate them in the ontology. Admittedly Ladyman and Ross end up endorsing what I call statisticalist-probabilism about reality. This both informs and is motivated by their conception of the nature of information, which is broadly statistical and not structural. However, this in turn seems to create problems for non-eliminative ontic structural realism as they formulate it. One adjunct note, however, is that Ladyman and Ross's view of the I universe reducing to the totality of non-redundant statistics and/or irreducible stochasticity seems to negate the need for any talk about relations as ontologically fundamental.

I reject that relations are the locus and source of the identity conditions of what ontic structural realists refer to as intrinsic identity of entities in the ontology. Here are my starting points for the idea of heterogeneity:

[5] In my defence, Everrett's possible worlds QM is supremely mathematically elegant, but, ontologically, strikingly inflationary §3.4.3 p126

I. I reject the binary conception of non-uniformity, and suggest that *differentiae de re* are necessarily multi dimensional - like fields.

II. In accordance with 1., binary relations associated with *differentiae de re* are idealisations and abstractions away from reality, rather than any viable basis for real concrete (especially spatiotemporal causal) structure.

III. Structures are nonuniform bounded regions of natural kind heterogeneous fields, in which *differentiae de re* intrinsically inher.

IV. Fields contain discrete *differentiae de re*, but the *differentiae de re* are not ontologically prior.

The reason for (IV) is contingent: there have never been detected physical *differentiae de re* in physics in isolation, only those embedded in fields. It is the quantum field that is (defeasibly) contingently existentially prior. The ontological move being made here is not really the opposite of formalism driven ontological descent. It's not ontological ascent according to which we arbitrarily supplant apparently abstract and constructed elements of the model in the scientific theory with concreta. What I am instead suggesting is that we stop regarding these as an epistemic or representing level of ontology versus a represented I-ontology and instead approach the former as representations encoded from information abstracted out from the I structure using encoding mechanisms that include indirect approaches which call constructive encoding into service. This is where successful physico-mathematical predictive posits come from, and why they succeed [6].

At minimum it is not clear that relations are ontologically prior to structures where there is content heterogeneity (as contingently indicated by QFT particle physics.) I think it more likely that structure does not reduce to relations, and nor are they ontologically mutually supporting. So relata/objects are structures or else exist only by virtue of being picked out by relations, which are structures (Esfeld and Lam, 2010; Ladyman, 2014, Chapter 5.) But Esfeld and Lam (and Floridi) say structures are relations:

> According to this position [moderate ontic structural realism], neither objects nor relations (structure) have an ontological priority with respect to the physical world: it makes no sense to assign an ontological priority to objects, because instead of having fundamental intrinsic properties that constitute their identity, there are only the relations in which they stand. In other words, an object as such is nothing but that what bears the relations. As regards the relations, it makes no sense to attribute an ontological priority to them, for at least insofar as they exist in the physical world, they exist as relations between objects. We can therefore say that the relations (structures) are the ways (modes) in which the objects exist... (Esfeld and Lam, 2008, 4-5.)

[6] I believe the solution to the symbol grounding problem and to the nature of mathematical structures is to be found in this direction, and I start an analysis in chapter 3

This is close to my position as ontological priority is not given to relations. Yet something is wrong, even granted the disputes between where formal representing structure ends and the I-ontology begins, and even if statistical structure is situated between the theory ontology and the I-ontology. If objects are structures and structures are relations then objects are relations. An alternative is that "[i]f there are objects at all, these are derived from the structures as being nodes of structures, instead of structures presupposing objects" (Ladyman 1998, French & Ladyman 2003, French 2006; but see also the more balanced position in Ladyman & Ross 2007, chapters 2 to 5.) The attempt to fit structures with relations and relata in the ontology - whilst maybe eliminating objects yet keeping them as nodes of structures and as structures - is clearly strained logically and ontologically. The problems with reconciling the elements are what lead Esfeld and Lam to propose intermediate structural realism.

Moreover, putting concrete physical fields first (defeasibly) means that we avoid the effective formalism driven ontological descent and mathematical of non-eliminative ontic structural realism as it is broadly supported:

> fundamental physical features can with good reason be taken to suggest all the same conclusion, namely that the fundamental physical objects – whatever they are according to the theory under consideration – are parts (relata) of a physical structure in the sense of a network of concrete physical relations. These objects do not have any existence – and in particular not any identity – independently of the structure they are part of (that is, the relations they bear to each other)... French and Ladyman (2003) – consider OSR to be supported by a fundamental underdetermination about individuality in QM and about quantum fields in QFT. Ladyman and Ross (Esfeld and Lam, 2011, 143-4)

I am proposing instead using a field ontology that includes an identity thesis about structure that says structure and its content just are the defeasible, contingent best ineliminable candidate: M qua the quantum field and vacuum. This allows us to avoid commitment to the idea that things such as particles as emergent excitations in the quantum field have no content other than relations in which they stand to other emergent features of the field, which brings with it the stress of calling the relations involved physical. Instead, according to FOSIR they are an information sources that are realised as a causally induced configuration of a heterogeneous (in terms of feature structure and properties) bounded (arbitrarily and/or else by structural features) regions of the quantum field. This alleviates an overriding problem with non-eliminative ontic structural realism: it's *effective* anti-Aristotelian elimination of natural content. This elimination happens on a pragmatic basis - the Peircian scientific variety of pragmatism - and as such ends up approximating the kind of epistemic viewpoint that OSR is supposed to provide an alternative to. A field ontology with a bite-the-bullet defeasible identity between structure and the nonuniformities *de re* of the heterogeneous quantum field itself provides an acceptable (in terms of scientific metaphysics) and useful middle ground between Arisotelian mysterious intrinsic properties and the elimination of all but bare content-less structure that is the hallmark of most non-eliminative ontic structural realism.

Moreover, *continuous* heterogeneous or nonuniform field structures seem - brutely and contingently - to be real things according to other assertions by Ladyman and Ross and F&L, and other OSR supporters beside. Their existence also seems to complicate if not negate the idea that structures require or arise out of discrete relations between discrete entities of some kind. I have claimed the scientific metametaphysical commitments of Humphreys and Ladyman and Ross as my own, and so I must find in physics a precedent for my claim about heterogeneous fields as prior to relations, and as the basis of structure. According to the physicalist reductive non-eliminative ontic structural realism that I am proposing, relata and relations are discretisations from existing structures. They are bounded substructures (and therefore as I will argue below information sources) that may stand in relations to other bonded substructures - selections of structural features with properties bound to them or realised by them. This is not unlike Ross and Ladyman's position according to which objects are derived from structures as the nodes of structures. However, the term node is abstractive as well: nodes are abstract representations of structured entities in network diagrams and directed graphs and other mathematical nets and meshes.

I think that the recognition of relations as having ontological priority is an unwanted left over from Worrall's ESR and was never properly dealt with in the proposal and formulation of OSR. We don't need this to defeat PM: we can kill it in other ways. It's the unreasonable effectiveness of physico-mathematical posits in physics that matters - not the truth or falsehood of statements in natural or theoretic language according to some referential context. It's the optimistic meta-induction that Floridi mentions (Floridi, 2008a) that is the right response: the theories keep working and making astonishingly accurate predictions despite the logical falsehood of some of the epistemic statements encoded into them. The best explanation for this in information theoretic terms - including statistical terms relating to uncertainty - is that there is an external I-obtaining set of structures and information sources that constrain the results and predictions of the theory, and that these deliver effectiveness and correctness despite linguistic-epistemic error. The whole system seems to involve a tolerance for inaccuracy as noise in the very real sense of a signal to noise ratio.

The heterogeneous information source-structural realism I am proposing is FOSIR: (quantum) field ontic informational structural realism. Here are its primary features and points of difference from other versions of OSR:

1. All structure is spatiotemporal causal structure or structure that reduces to such structure compositionally (although the component strutures or elements of them may be distributed in space and time) and this includes mathematical structures in what is close to an immanent realist sense.

2. It is not salient, nor fatal, that structure might defeasibly reduce to structure all the way down with no in principle terminus (contingent on the findings of physics.)

3. Structure is realised by nonuniformity and natural kind heterogeneity in multidimensional quantum and classical fields: not by idealised or abstract (or abstracted) point to point or node to node relations or by data structures, but -

    i. **Relations** are retained in the ontology as selections of structure and associated properties from the structure or substructures. There is no need to define them as determined by discrete relata, but they can be thus defined.

    ii. **Entities** are retained in the ontology as substructures which are arbitrarily bound multidimensional heterogeneous fields. Such bounded substructures in the heterogeneous multidimensional spatiotemporal causal field provide the ontic basis of or are *information sources*.

4. **Properties** are distributed across the nonuniform bounded quantum field regions either homogeneously and evenly or heterogeneously, and thus across the structures. Any discrete selection of substructure including at a physical non zero-dimensional location of an idealised point can have empirical causal properties (realised due to the structure and the structures that it reduces to and the nomic constraints that operate upon and within them and the interactions between the substructure and other substructures that may or may not overlap or intersect with it.)

I will call 3. the *no abstract wireframe* principle (see my earlier multiple/partial wireframe argument §2.3 p62), and I will label the principle from OSR that it negates, which I will refer to as the abstract wireframe principle:

> Structure always consists in certain specific, concrete relations, these relations being as determinate as intrinsic properties are supposed to be (Esfeld, 2009a, 5.)

The *no abstract wireframe* principle is the expression of the hypothesis that structure does not reduce to nor ontologically depend upon relations between relata like some kind of mesh made up of nodes connected by concrete relations (the abstract wireframe principle), but instead is realised in I terms as a contiguous and continous heterogeneous spatiotemporal (and multidimensional) field comprised of similar fields - all the way down (defeasibly and if necessary) in reductive terms. The mesh is just a substructure - a selection of specific features from the total structure. It does not determine the I nature of the entire structure to which properties are being imputed/ascribed.

Ladyman and Ross approach this in their explication of non-eliminative ontic structural realism by referring to the conclusion of Michael Redhead:

> [R]ealism about what? Is it the entities, the abstract structural relations, the fundamental laws or what? My own view is that the best candidate for what is 'true' about a physical theory is the abstract structural aspect. (1995, 2) (Ladyman et al., 2007, 139)

My suggestion is that a sound justification for the application of the no-miracles argument which Ladyman and Ross endorse as part of the primacy of physics constraint is that the abstract structure redhead speaks of - the structure in the model and theory arising from the web of relations described by it - is in fact an abstracting out of part of the information from the I-existing structure of the phenomena being investigated, and that the relations that form that representing 'abstracted-out' structure are an encoding of partial structural CICS information *from* the phenomena in question. Cao observes:

> But then one may ask, what ontologically constitute structures? The question is essentially the same question as to which, a structure or its parts, should be taken to be ontologically prior over the other. The answer depends on specific situation. A structure, characterized only by its invariants, may be ontologically prior over its constituents (relata in the relational structure, either as unstructured raw stuff or as place-holders.) But if a structure is formed by its constituents through a structuring agent and characterized by structuring laws, which govern the behavior of the constituents and hold them together to be a structure, then the constituents certainly enjoy ontological priority over the structure as a whole. (Cao, 2010, 212)

I suggest that Cao's second option above (the constructivist situation - see Ibid 213) is instead still reducible to - or else collapses into - something like the first option: the agents and structuring, and the constituents, are identified as (albeit causal) elements emergent from the quantum field such that "the existence and characteristics of the constituents are derived from the structure." Cao asserts that the second option consists of:

> causally effective properties of the constituents (such as the charges of the electron and proton) that make it possible for a structure (the atomic structure of hydrogen) to be formed through the causal interactions of the constituents content...(Ibid)

He does so because the basis of his distinction is *causal powers*. However, I do not need this hypothesis - nor causal powers - to sustain FOSIR, and I don't think Cao needs this either. I have no dog in the race with respect to causal inducement except the idea that fields transmit structural change by continuity (including the non-contiguous variety required for entanglement - defeasibly.)

I suggest that the realist about the scientific image is a realist about the I heterogeneous field (the fluctuating vacuum of QFT) as well as about the selection of relations and entities (configured substructure information sources) and other substructures selected and encoded from or out of it. Another way of putting this - in informational terms - is that if information existentially depends upon structures realised as bounded multidimensional regions of hetergeneous fields (which all reduce to the quantum field one way or another), then the realist about the scientific image is a realist about the information in the field I-existing.

Info-structural Properties and Relations

Just as I reject trope bundles for fields and M, and objective grounding, I reject the need for such metaphysical posits as quiddities for the realisation of properties and haecceities for the distinguishing of individuals, as well as clusters of dispositions for the realisation of properties. According to both ESR and OSR the problem with objects is that any intrinsic properties that they are supposed to have are wholly unverifiable. Properties are only identifiable by the external relations in which entities stand to each other and the effects between entities that those relations capture for measurement and (Esfeld and Lam, 2008, 3-4; Lewis, 1999, 114.) Properties according to OSIR reduce to the nomic interactive causal propensities of field CICS.

Now, Ladyman and Ross have to find a way to retain objects and the properties that supposedly inhere in them. Esfeld and Lam suggest that they are limited in terms of options, with which assertion I agree:

> As mentioned above, insofar as the radical ontic structural realism ofF&L admits objects at all, it has to reconstruct them as something like bundles of relations (more precisely, nodes of relations) (Esfeld, 2009a, 6.)

Esfeld decides to deal with properties by redefining relations such that intrinsic properties are eliminated:

> [A] metaphysics of relations based on a characterization of quantum entanglement in terms of non-separability, thereby regarding entanglement as a sort of holism. By contrast to a radical metaphysics of relations, the position...recognizes things that stand in the relations, but claims that, as far as the relations are concerned, there is no need for these things to have qualitative intrinsic properties underlying the relations. This position thus opposes a metaphysics of individual things that are characterized by intrinsic properties... (Esfeld, 2004, 601.)

This is fairly motivated by "the rationale behind a metaphysics of relations is to avoid a gap between epistemology and metaphysics." However, notice again that now the objective is to avoid the premise that intrinsic properties underly the relations, whereas in the afforementioned cases relations *reveal* the intrinsic properties, which are otherwise inaccessible.

My suggestion is that objects or nodes are substructures (the use of the term 'nodes' implies an ambiguity with points) and information sources, and that their properties come from two sources:

1. The nomic constraints acting via causal pathways upon the structure and its substructures (all realised by fields.)

2. The configuration or arrangement of the bounded substructures and (the interactive characteristics of) the heterogeneous fields that realise them.

The apparently intrinsic properties of any given bounded (sub)structure (information source) or bounded region (not necessarily continuous) or a multidimensional heterogeneous field (the heterogeneity is the ontic basis of the configuration of the structure inside the boundary of the source) are realised by the properties of the structures and thus the sources to which the source/structure reduces and of which it is comprised, and these are realised by causal impetii governed by nomic constraints and the different types of field. Presumably we should allow different types of heterogeneous field. This is in keeping with physics, according to which difference particles are associated with quantisation of different fields (Tong, 2007.) The heterogeneity is all that is required to deliver the structure, but for properties something more is needed. I take it that a field type is indicated by the way in which it interacts with causally effected nomic constraints, and that differences in the interaction result in differences in properties from one part of a field to another.

This approach may seem close to a return to Lewis' Humean supervenience thesis according to which "at the basic level of the world, there are only local qualities in the sense of intrinsic properties instantiated by space–time points or point-sized particles or field sources" (602.) However according to my approach, it is not the case that "everything there is in a world like ours supervenes on the distribution of basic intrinsic properties over all space–time points". Instead, the subtle but very relevant difference is that properties are heterogeneously distributed across intersecting fields. I-obtaining fields are mathematically described in terms of a quantity of something being distributed through spacetime (Tong, 2007, 5; Zeidler and Service, 2009; Lancaster and Blundell, 2014.) What that something is depends upon the nature of the field such that different fields are distributions of quantities of different natural kinds, or one natural kind out of which different natural kind particles are somehow produced by excitation (energy input.) Properties emerge from the natural nomic constraints acting upon fields (themselves fields) and from the quantisation of the any multidimensional field. Another way of putting this is that both spacetime points and relations are just selections or the picking out of information from the existing field (Rickles, 2012, 143.) Choose any two so called points in a field, and there are an infinite number of spacetime points between them.

Here is how my approach differs from Lewisian Humean supervenience:

1. The fields are real, but the points themselves are just positions within the field. The properties emerge from the operation of physical nomic constraints upon the fields, and their empirical interactive effects on other fields, and are distributed not across points but heterogeneously through fields.

2. Fields are real, points are abstractions of information from fields, particles are features in fields and are not points in the either a mathematical or semi abstract sense.

Relations may be said to exist between points (although it is not clear how relations could actually physically exist as concreta in the way that arbitrary positions in the field which could be called quantised point sources can.) If we are following our mandates to put scientific metaphysics first, then it is significant that particles can be identified as points according to Lewis' metaphysics, Our best physics suggests that it very much looks like fields (which may or may ot be something like strings) come before particles. Particles are quantisations of a field that can be located by a point in the field. No quantisation at a point - no particle. The photon was the first particle to be described first in terms of a quantisation of fields, and physicists progressively discovered field-quantisation based physical explanations for numerous other particle types (Weinberg, 1995b, 3, 15.)

One type of heterogeneous field (a region of the quantum field excited in a certain way to produce one type or another of particles) will respond to the causally induced effects of nomic constraints differently than another. For example - different heterogeneous fields of matter and energy sitting in the same gravitational field - modelled by different effective field theories - are operated upon causally somehow by that gravitational field regarded as a causally active nomic constraint, and various kinds of energy field interact with different physical structures differently.

None of this in any way means that information is somehow matter, although defeasibly there is a chance that it may contingently turn out to be or reduce to the latter or configurations of the latter, since energy is so central to field in definitional and ontological terms.

Information pioneer Wiener would have disapproved:

> "Information is information, not matter or energy" (Wiener, 1961, 132.)

I have referred in this section to casual nomic constraints and to causal interactive propensities. I now owe some discussion about what scientific metaphysics with a quantum field ontology allows me to say about causation.

3.3.1 Causality as Continuous Transmitted Field Fluctuations

Philosophers and ontic structural realists have long since identified causality as a problem for scientific realism and structural realism. According to Ladyman and Ross, and Esfeld and Lam, it is not clear what it means to regard structure as causal - even if there is a strong intuition that the correct kind of conception of structure is that it is physical (Ladyman, 2014, 71.) The ontic structural realist whose position is closest to my own is French. He deals with causality by rendering it intrinsic to relations that comprise a structure:

> However, although being a realist about structures and an anti-realist about causality does not seem to be an incoherent combination, this is not the only alternative. Again, I'm not convinced that the claim that causality has some 'active' component requires a metaphysics of objects and properties.Thus consider the question:

> where might this active principle be located? With the object or the properties? If the former then we obviously need to press a little further and ask for an account of objecthood which could accommodate such activity ... Obviously the idea of objects as ultimately bare substrata can't do the job; and equally obviously the view of objects as bundles of either properties or tropes forces us to look closer at the latter as the source of this activity. There are then further options: either each property that is causally active has some causal principle particular to that property, or kind of property, that is involved in the conferral of causal power on the possessors of that property; or there is some generic causal activity which together with the other features of properties confers such powers. (French, 2014, 216-7.)

I have not only dispensed with bundles, ground, and tropes as I-necessary existents or explanatory, I have also included relations in this - against most existing OSR and probably against the scientific metaphysical intuitions of proponents of the same. Causality, however, is not so eliminable on a contingent basis (Ney, 2009; Handfield et al., 2008; Maudlin, 2007; Dowe, 2004; Kutach, 2013; Glynn, 2013. For my non-modal characterisation of causation, refer to §3.3.1 p113 .)

Determining a place for causality in OSR is difficult to do on an a-priori basis. I suggest, however, that when regarded contingently causality is less impenetrable. There is a mythologised 'microbanging' conception of causality that I, like Ladyman and Ross, reject as dispensible and as just wrong (Ladyman et al., 2007, 3-4.) As Cao has observed, historically physics saw the move from considering force as an entity, to viewing it in field-theoretic and ontological terms:

> [T]he change from the mechanical perspective to field-theoretical perspective in looking at physical interactions was accompanied by or resulted from the replacement of a commitment in which force was taken to be an independent entity, ... Of course, the view in which interactions are conceptualized as the processes of emission and absorption of quanta by interacting entities through exciting the general background of the vacuum signals is still another conceptual revolution. (Cao, 2010, 208)

The conception of causality and statement of physicalism that I endorse are also governed by the primacy of physics constraint (the primacy of physics constraint) and PSR *about* information transmission at the level of I-ontology: I am not interested in trying to defend PSR in epistemic or semantic terms - only for I-ontology. PSR is understood to be an analytic basis of reductionist approaches to understanding quantum systems and quantum field theory (Rickles, 2008c, 187, 173-4.) Scientific metaphysics of the kind we are pursuing here only permits of such if there is contingent support for it. I do not have space for a full defence of a metaphysics of physical causality, but my approach involves the scientific contingent sustaining of the following assertions:

a. Information transfer and transmission is ineliminable from both I-obtaining natural systems and from the investigation of such (even scientific instrumentalism requires that information goes from the instruments to the theory)

b. According to the best (all, in fact) science, and maintaining the no miracles argument, physical signal pathways are a necessary condition for information transmission (Hawking, 2014)

c. Causal pathways just are or reduce to signal pathways, necessarily (every causal pathway is a signal pathway)

d. Accidental correlation between a source and a destination structure sans signal pathways does not constitute information transmission (unless there is an observer to add additional encoding signal pathways [7])

FOSIR Causation My characterisation of physical causation is consequently that it is identical to casual inducement of configuration of I-obtaining structures and structures that reduce to I structures (nonuniform regions of quantum fields), and that physical causation is a necessary and sufficient condition for information transmission.

There is an entire philosophical literature stemming from Humean scepticism (Hume, 1748) and from counterfactual analyses like that offered by David Lewis about causality that regards considering causality in realist terms as reifying an unecessary metaphysical glue in the same way as I refer to trope bundles, property bundles, and even relations of certain kinds in §3.2 p83. (Fair, 1979, 223; Woodward, 2010; Lewis, 2000; Lewis, 1979; Menzies, 2004; Kutach, 2013; Maudlin, 2007; Dowe, 2000.) I have elected the realist physicalist conception of causation on a defeasible basis, in agreement with Ladyman and Ross, French, Cao, Alyssa Ney, and a much earlier David Fair - all of whom have differently nuanced interpretations of physical causation and causation as physical (Berenstain and Ladyman, 2012, 158; Fair, 1979 220; Ney, 2009, 740-1. See also Braddon-Mitchell, 1993.)

The conception of causality that I recommend is realist about causal pathways, and regards them as functionally and ontologically ineliminable from the physics of signal transmission (which is also in keeping with PSR.) Signal transmission is something that I will argue is a strong indication that something like a ‘banging together’ type of causality - based on fields as structures rather than objects - is real. Put brutely: there is stuff that bangs together, and that stuff is or reduces to physical (by the definition presented below) fields, and it isn’t exactly ‘banging together’: more like ‘continuous pulling and pushing’ or ‘pulling and pushing in a continuous medium’: a kind of transmitted flux. For those that think this latter statement hopelessly inadequate, I present a continuous conception of the same, the idea of which is that proximate fields and parts of fields are continuous with other bounded fields, and are necessarily affected by

[7]See §5.4.1 p190

fluctuations in those neighboring fields. So the banging together of fields is a transmission of energy through field boundaries (something like this has been presented by Fair, 1979, 228-230, 233.) This is in fact based upon what are now fairly familiar observations in QFT:

> An important development was brought out in 1932–33 by Heisenberg in his work on the compound model of neutron, in which he developed the idea that the nuclear force consisted in the exchange of pseudo electrons. The idea was taken over and further developed by Ettore Majorana. Then a crucial step was taken by Enrico Fermi in his work on the beta decay of 1933, in which interactions were conceptualized, not in terms of the exchange of existing particles, but in terms of the couplings of fields, or the creation and annihilation of the relevant quanta at the interacting point. The tacitly assumed conceptual foundation of Fermi's theory was the vacuum fluctuations, which under certain constraints result in the creations and annihilation of real and virtual quanta. A crucial step in laying down this foundation was taken by Niels Bohr and Leon Rosenfeld in 1933 when they investigated the measurability of the field, which brought the idea of field fluctuations into the physics community. This, combined with Heisenberg's uncertainty relations, paved the way for the idea of local fluctuations of the field, whether it is in the vacuum state or in excited states. (Cao, 2010, 206.)

Put yet another way: snooker balls don't seem to be connected in terms of occupying each other's space when they collide, but according to contemporary physics they're really made up of fields, and the constituent fields are overlapping and interacting at impact (Deutsch and Hayden, with whom I disagree about Everett's interpretation of QM, have expressed a similar requirement they call *contiguity* (Timpson, 2005, 320.) Put still another way, Hume's statement that we don't know what the nature of the (physical) relation of causality is between snooker balls is arguably answered by field theories in physics. Particle interactions in quantum systems are well described not only because all fundamental particle tokens are identical to each other for each particle type, but because their interactions are field based.

According to my approach, the ineliminable objective basis of signal pathways is physical causal pathways, and their characterisation as physical is rooted in contingency, measurement, and empiricism, rather than any a-priori metaphysical dogma.

Causal Configuring and Configurations

A statement of the idea of causal pathway based inducement of configuration of a structure and its salience to physicalist non-eliminative ontic structural realism is approximated (in loose contingent metaphysical terms) by Ladyman and Ross:

> However, understood in terms of claims such as 'The Kreb cycle is an unobservable structure that underlies cellular metabolism', or 'Mobile telephones work because microwaves propagate between them and telecommunication masts and satellites', where 'microwaves' describes recurrent structure for propagating a certain class of influences, then we do have knowledge of the unobservable. (Ladyman and Ross, 2013, 127.)

The phrase "propagation of a certain class of influences" approximates the idea of transmission of information by causal inducement of configuration of structure. Like Cao and Ladyman and Ross I regard that scientific realism at minimum requires the inclusion of causation in the *I*-ontology (Ladyman and Ross, 2013, 144-5; Cao, 2003b, 59; Esfeld and Lam, 2010, 156.) I suggest that furthermore, and perhaps more importantly, representation requires information transmission which is not possible without signal pathways, and signal pathways are ineliminably causal in nature.

Cao, Dennett, and Ladyman and Ross make extensive use of the concept of configuration (Cao, 2003b, 59-64; Dennett, 1991; .) This is hardly surprising as it is an intrinsic part of phase spaces and other mathematical representations of physical systems, and is familiar in physics from the configuration spaces of gauge theories. Crucially, despite the non-reductive and ant-reductive overtures of Ladyman and Ross and Dennett, the concept of configuration is common between them and underdetermines my own. Real patterns in empirical theories are still determined by the causal inducement of arrangement/configuration of the representing structures. According to my approach, the configuration of a representation in phase space is still causally induced and encoded according to the mechanisms so far discussed: complexes of encoding apparatus and rules for achieving partial representations.

Reference to configuration has a long history in science and the philosophy of science. According to FOSIR and the CICS conception of information, partial representation is representation of part of the information of a system: of part of the configuration of its spatiotemporal structure (refer also to the final chapter.) The British emergentists - particularly C.D. Broad - had an early conception of the configuration of a system. It concurred with ideas in classical mechanics in that it was basically the idea of the arrangement of a system's particles. However, for the emergentists, the arrangement of the microconstituents of a physical system resulted in causal powers exerted as what Brian P. McLaughlin has termed 'configurational' forces. The emergentists thought that "some special science kinds from each special science can be wholly composed of types of structures of material particles that endow the kinds in question with fundamental causal powers" such that "the powers in question 'emerge' from the types of structures in question" (Bedau and Humphreys, 2008 20-21, 34.) The concept of special configurative forces is of course largely defunct. However, causal relations have remained indispensable for scientific explanation.

Ubiquity of Information and The Quantum Field

Information exists in and essentially is the causally induced spatiotemporal configuration of the system (refer to §3.3.1 p114 for more detailed argument.) Configuration here is the arrangement of the physical data in the structure. Physical Structure is the real ontic basis of information in both Shannon's theory and Dretske's conceptions of information, since sources and source states are physical structures. The same is true on a similar basis for Floridi (by structural realism), Devlin (situations) and Chalmers (the double-aspect principle.) All mathematical structures and rules used to represent necessarily require physical structure to be inscribed or otherwise realised. All cognitive structures employed in doing mathematics or any other simple or complex cognitive function require physical realisation as physical structures.

Any meaning of the data is due to its status as intrinsic semantic information: what the spatiotemporal configuration indicates about the physical structure and properties of the physical structure(s) that caused it. A structure naturally indicates something of the cause of its configuration. If unnecessary subjectivist and absolute idealist kinds of confusions are not permitted to muddy the waters, then this is all but undeniable: neither subjective propensities to bet, epistemic probabilities, nor abstract observers are a necessary requirement for the existence of causal pathways. The configuration (intensity, energy levels, intervals and frequency) of gamma rays or x rays form a celestial x-ray source indicate something about the structure of the celestial source (the frequency at which it is spinning, for example.) These assertions are broadly defensible on intuitive, empirical and scientific grounds. According to this ontology, information is – like physical structure – ubiquitous.

David Chalmers may have been the first philosopher to propose that the ubiquity of information is objectively true and intuitively obvious. The best way to quickly grasp this idea is by a kind of loose intuitive reductio: try to think of somewhere that information does not exist. According to subjectivism about information, it can only exist where there is a sentient epistemic agent: that information is some kind of agent phenomenal or cognitive content, or some resource that gives rise to the same. However, this kind of assumption just seems wrong when one asks whether neurons, non-sentient organisms - and especially DNA and RNA - would contain information even in the absence of an epistemic agent (Hutter, 2012, 408-12.) It seems hard to deny that objectively they would contain, generate, consume, process and pass information even if no epistemic agent of any kind ever existed to perceive them (and they did so for millions of years.) An ontology which considers the "fluctuating vacuum field as its basic entity" - that of QFT - supports this notion in conjunction with a causal I CICS conception of information. The random element of the posited nature of the vacuum field may trouble *ontic-physicalist* PSR if the argument that randomness is uncaused can go through (Cao, 2010, 204-5; Kuhlmann, 2010a, 1630; Swanson, 2017, 4-5.) This does not seem to be a significant problem for my approach: according to physics the vacuum state or zero-point quantum field regions are never empty of structure: especially in Minkowskian four dimensionalist terms.

A putatively more secure agent-centric conception requires only that the agent be an organism of some kind: that information is only something that is definable with respect to an organism with component subsystems that consumes it or produces it. However, again we are then required to deny that no information objectively exists in suns, pulsars, molecules, proteins, electromagnetic radiation, in quasi-periodic oscillations from celestial x-ray sources, and so on, in the absence of any consuming organisms or perceiving agents. We would have to say that no information is emitted from the configuration of a pulsar (its frequency of rotation, mass, beam energy levels etc. Zeidler and Service, 2009, X, 25; der Klis, 1988) in the absence of organisms (cognitive or otherwise) which can somehow register or sense the emission. So strong is this intuition that information is agent-centric that it leads Chalmers to feel able to propose the unintuitive thesis that information and experience are inseparable: wherever there is information, there must be an informational entity or system realising experience along with it (Chalmers, 1996, 282-6.)

I suggest that - according to science and especially according to ontic structural realism - information is indeed ubiquitous. Trivially and defeasibily, physical structure - and structures abstracted from but necessarily supervening upon and reducible to physical structure - are ubiquitous because they reduce to classical fields and all classical fields reduce to (regions of) the quantum field and vacuum. According to FOSIR, information is therefore ubiquitous. Were information existentially dependent upon a subjective agent, then Chalmers' assertion of ubiquity would be necessarily false in the absence of - say - an appropriate version of objectively real idealism.

3.4 Other Field Ontological Alternatives

3.4.1 Why not Nominalism about Information?

Although I find it to be *initially* intuitively appealing, I reject that eliminativism and/or some kind of nominalism about information is true (Levy, 2011; Griffiths, 2001.) My intuition favours naturalistic liberal pluralism at higher levels of abstraction - at the level of information measures, of formal logical, logico-mathematical, and physico-statistical theories of information [8]. I find the latter to be the most convincing alternatives (Floridi, 2009b 13-15.) I will endorse

[8] I refer to the technical conception of levels of abstraction in computer science and software engineering, which meshes with the conception of abstracting out or removal of data and structural details irrelevent to the specific modelling, explanatory, or computational task at hand at a given level of focus and explanation. Many philosophers of science refer to the same technique under the rubric of levels of abstraction, explanatory levels, and/or scale variability (Woodward, 2010; Mitchell, 2009, 28, 109, 114; Wimsatt, 2006; Bermudez, 1995; Neuroscience: Owens, 1989; Physics: Wilson, 2010.)

I regard that an understanding of abstraction in terms of the discarding of noise or irrelevant information and/or the black-boxing of details is a given for scientists and engineers, and that philosophers should not have any trouble with it as a technical term. For a development of the terminology refer to Floridi, 2008a; Van Leeuwen, 2014, Floridi, 2008b; Computer Science: Ratti, 2015; Ganascia, 2015.

pluralism at higher levels of formal theorising and modelling. However, I will argue that thoroughgoing eliminativism and nominalism do not hold up under scientific metaphysical scrutiny with respect to both realism about information and the nature of information and a metaphysics thereof. I will be arguing that realism about information is implied by its indispensability to science, along with inference to the best explanation. Anti-realism about information does not survive these either intuitively at first blush or upon more careful scrutiny. Asserting or adducing the nature of information is not nearly so trivial a challenge.

The approach I am taking involves an identity thesis between the I-existing ontic structure that ontic structural realist scientific realists endeavour to be realist about, and physical selections of structure *in re* the universal quantum field (all fields combined) and vacuum (where fields are in ground states) across all of spacetime. Approaches to how the fields of quantum field theory exist often involve process interpretations, nominalism, trope bundles, particle interpretations, and field interpretations. I am interested only in the latter: field interpretations. According to my informational ontology, fields are at the bottom of the ontology of the world, but they constitute stochastic dynamical (embodying fleeting excitations and fluctuating states) CICS information sources.

My approach is to establish the aforementioned ontic identity to help provide a basis for the nature of information, but there is also support for the idea of nominalism about information in the philosophy of physics. For example, taking his lead from Fred Dretske's definition of information as an abstract commodity, Christopher Timpson refers to the term 'information' as an abstract noun only:

> The puzzle that seems to be posed by the examples of teleportation and the like is over the question 'How does the information get from A to B?'. This is a perfectly legitimate question if it is understood as a question about what the causal processes involved in the transmission of the information are, but note that it would be a mistake to take it as a question concerning how information, construed as a particular, or as some pseudo-substance, travels. 'Information' is an abstract noun and doesn't serve to refer to an entity or substance. Thus when considering an information transmission process, one that involves entanglement or otherwise, we should not feel it incumbent upon ourselves to provide a story about how some thing, denoted by 'the information', travels from A to B; nor, a fortiori, worry about whether this supposed thing took a spatio-temporally continuous path or not. By contrast, we might very well be interested in the behaviour of the physical systems involved in the transmission process and which may or may not usefully be said to be information carriers during the process. (Timpson, 2005, 331)

I do not think, and nor am I arguing, that information exists in the ontology as some natural kind. The identity thesis I have proposed between the

I-structure about which ontic structural realists are realist and selected *in re* I-obtaining quantum field structure does not involve taking information to be the same natural kind as I-obtaining fields and/or their *in re* structure. I am in agreement with Timpson here. My argument is that a way in which structures are I-configured and exist in the system constitute its functionally effective information (and intrinsically semantic - see §5 p175.) To paraphrase Timpson, the information gets from A to B by way of causal processes and structures - the causal inducement of configurations in structures comprising a signal pathway in transmission media. I am referring to such causal processes and their structures as linked information sources and their causally induced structures as information. The classical model and its contemporary adaptations allow for this - a channel can be treated as a source and any stochastic process is a source. Moreover, the causally induced downstream configurations of structure are all natural representations of those upstream causal structures that induced them.

Spatio-temporal continuity is too strong a requirement, from a scientific metaphysical perspective, to place upon the transmission or information. This is mostly due to quantum non-local effects and the Bell theorems. Note that it does not follow from this that structures that co-incidentally co-vary are realising information transmission or transfer (Not independent of any observer, anyway. See §5.4.1 p190.) I require only *causal* continuity (see §7.3.1 p252.) Note also that it is not clear that QFT cannot in principle provide an explanation for the results of the Bell theorems and the apparent failure of hidden variable posits, but none is apparent yet.

According to the classical theory, message transmission reduces to signal transmission from a source through a channel that involves transducer based *encoding*, which I will later argue can occur naturally. Transducers by definition generally involve energy transduction. The terms 'code' and ' encoding' have been cited as having metaphorical and/or nominalist use in molecular bioscience (Godfrey-Smith, 2000.) It looks like further support for pluralism and nominalism that the term code also gets used for the physical interactions that effect protein folding. Returning to Dill et. al.:

> Prior to the mid-1980s, the protein folding code was seen as a sum of many different small interactions—such as hydrogen bonds, ion pairs, van der Waals attractions, and watermediated hydrophobic interactions. A key idea was that the primary sequence encoded secondary structures, which then **encoded** tertiary structures. However, through statistical mechanical modeling, a different view emerged in the 1980s, namely, that there is a dominant component to the folding code, that it is the hydrophobic interaction, **that the folding code is distributed both locally and nonlocally in the sequence**, and that a protein's secondary structure is as much a consequence of the tertiary structure as a cause of it...Similarly, tight packing in proteins implies that van der Waals interactions are important (28.) However, the question of the folding code is whether there is a dominant factor that explains why any two pro-

> teins, for example, lysozyme and ribonuclease, have different native structures. This code must be written in the side chains, not in the backbone hydrogen bonding, because it is through the side chains that one protein differs from another...Sequences that are jumbled and retain only their correct hydrophobic and polar patterning fold to their expected native states... in the absence of efforts to design packing, charges, or hydrogen bonding. Hydrophobic and polar patterning also appears to be a key to encoding of amyloid-like fibril structures (236) (Dill et al., 2008a, 291. Emphasis added.)

Notice the ontologically non-inert reference to 'patterning', and that the way that amyloid-like fibril structures are generated is by being causally 'coded' - the inference being that they get their functional dynamical conformation-configuration from a natural encoding process. The process can be said to have an alphabet of possible 'codes' - conformations and associated properties with evolved teleological rules for where and how they fit with other conformations. Thus the application of 'encoded' and 'code' is not heretical to the I natural system as a number of philosophers have suggested (Godfrey-Smith, 2007.) Scientists like Dill et. al. know more than enough about classical theory *and* that of Fisher and Kolmogorov (and the derivatives of those theories - MDL, Solomonov, Kullback-Leibler.) It seems coherent to claim that protein folding codes and the genetic code have non-trivially similar causal-structural components and that both involve - ineliminably - the causally induced configuration of structures, and subsequent transmission of causally induced representations (existing on the same basis) as well as inducing of functional structures (Griffiths and Stotz, 2013.) At the core of all of this is the transmission of intrinsic structure-reducible representations of causally upstream systems acting as information sources (sometimes very large complexes of them.) There is little reference to information using the word 'information', but if classical and algorithmic information measures were applied I suggest naturally encoded CICS would be the bottom of what got measured. In another recent paper Dill et. al. refer to information using a Shannon-like interpretation and other measures based upon energy ratios as indirectly informative giving secondary information about certain structures and their properties.

> By definition, ϕ values are fundamentally energetic quantities, related to changes in the protein's stability and folding rate. Do ϕ values also give information about the structures that describe the kinetic "bottleneck" or transition-state? (Weikl and Dill, 2007)

There exist both general metaphysical nominalisms regarding the nature of such things as abstracta and particulars, and mathematical nominalisms about numbers and mathematical structures. Metaphysical nominalisms tend to be about I ontologies, and mathematical nominalisms about formal representations thereof. There is more than one kind of metaphysical nominalism (Kuhlmann, 2010a, 137-40; Armstrong, 1978.) General metaphysical nominalisms are differentiated primarily by different accounts of abstract entities including that they are universals, trope bundles, and property bundles - among other options (Armstrong, 1997; Armstrong, 1978; Simons, 2014; Armstrong, 2010;.) Mathematical nominalism (fictionalist and non-fictionalist.) Mathematical nominalism is relevant to an investigation of the existence and nature of information since some philosophers have regarded information as being reducible to or otherwise related to mathematical constructs and/or structures (especially probabilistic constructs and principles.) General metaphysical nominalism is relevant since information is often associated with Platonic abstracta of one kind or another (platonism about information.) The relevant question is whether or not the existence and/or nature of information should be viewed nominalistically.

It is apparent that a fictionalist nominalism like that familiar from the philosophy of mathematics is not appropriate for addressing the question of the nature of information. The greatest difficulty, and primary premise for this claim, is that - unlike mathematical entities - it does not seem like information can be regarded as a fiction or as not real by science and in scientific theories without harm to the empirical theories. It looks like expunging references to mathematical entities might leave the empirical theory in tact according to fictionalist nominalism about mathematical entities (Field, 1980), but expunging references to information (or to information theoretic dynamics) will do harm to both the semantics and implications of most scientific theories. Field himself pointed out the difference between mathematical terms/entities and theoretical terms/entities (intended to identify real phenomena in nature):

> To put it a bit vaguely...if you take any body of nominalistically stated assertions N, and supplement it with a theory S, you don't get any nominalistically-statable conclusions that you wouldn't get from N alone. The analogue for theories postulating subatomic particles is of course not true: if T is a theory that involves subatomic particles and is at all interesting, then there are going to be lots of cases of bodies P of wholly macroscopic assertions which in conjunction with T yield macroscopic conclusions that they don't yield in the absence of T; if this were not so, theories about subatomic particles would never be tested (Field, 1980, 9.)

It's evidently not true for references to physical structure and information or informational dynamics either.

3.4.2 The Analytic A-priori: Fields as Trope Bundles and the Spacetime Manifold

Andrew Wayne discusses the historical role of the ether as the substantial substrate in which properties and fields were embedded in various scientific theories of the 18th and 19th centuries (Wayne, 2008, Dieks, 2002 ,1-4.) Science progressed from this conception and ontology to one in which Einstein's spacetime manifold M replaced the ether as the medium in which fields and their properties are embedded. Wayne notes that M is unlike the original mechanical ether and more like "H.A. Lorentz's theory in which the electromagnetic field consists of a collection of properties of an immaterial ether" since M, like Lorentz's non-mechanical version of the ether, was immaterial (Ibid 2-3.)

Wayne notes that "Field theories with a material ether ontology are the quintessential scientific articulation of a substance-attribute metaphysics" according to which the material and mechanical (causal) ether can exist without the field, but the field is existentially dependent upon the ether. Points exist or are picked out in the substance of the ether. Those points together with their attributes make up fields. Sustaining points with attributes comprising fields that have to be physical in Lorentz's nonmaterial ether - and in M - presents difficulties:

> It appears that such an ether could play no useful role in the ontology of physical field theory. For these reasons we may be inclined to augment Lorentz's immaterial ether with certain geometrical properties,such as topological, differential and metrical properties, so that it can fulfill the role of indexer and individuator of field properties. This appears to be a promising strategy and it is...the direction taken by the ontology of 20th century field theories. That fields are the properties of a substantial substratum remains the received view to the present day. (Wayne, 2008, 4.)

Importantly, and not without sound deference to scientific metaphysical principles, there are similar problems with getting physical fields to existentially depend upon M as the apparently non-material successor to Lorentz's immaterial ether:

> We ought to question, however, whether the spacetime manifold, an immaterial ether with geometrical properties, can fulfil its role as the substantial substratum for classical field theories. . . Fields in contemporary physics are material objects; they contain mass-energy and interact causally with other material objects. (Ibid., 5)

However, I suggest that apart from the fact that Wayne is probably wrong that contemporary physics does not regard fields as basic (he does not mention the vacuum), it is also a confusion to regard that physicists think that fields reduce to a non-material M. Nevertheless, this is again the problem of dual ontological commitments in physico-mathematical empirical theories giving rise to mathematical collapse. It is understandable from an instrumentalist and constructivist perspective - and from the perspective of practical science - that in the computational machinations of a theory there are no commitments to parts of the ontology expressed as mathematical concepts existing mind, language, and computation independently. M is formulated and characterised as a kind of mathematical stratum in which to embed classical physical fields, but there is no commitment to its I existence:

> When relativity theory banished the ether, the spacetime manifold M began to function as a kind of dematerialized ether needed to

> support the field . . . [I]n postrelativity theory it seems that the electromagnetic field, and indeed all physical fields, must be construed as states of M. In a modern, pure field theoretic physics, M functions as the basic substance, that is, the basic object of predication (Wayne, 2008 Wayne quoting Earman, 1989, 155)

Wayne regards that a metaphysical solution is called for pursuant to scientific realism, if not physicalism. It is at this point that Wayne's deference to more traditional 20th century metaphysics and metametaphysics becomes apparent, as he presents an a-priori metaphysical solution in terms of fields being regarded as bundles of tropes, and thus as universals in the a-priori analytic sense. I've neither space nor motive to investigate this approach in depth as I have already rejected its basis in deference to Ladyman and Ross style scientific metaphysics.

I have sympathy for Federico Laudisa's reception of Meinard Kuhlman' similar trope bundle attempt at a metaphysics for quantum field theory, since Laudisa's doubts emphasise - in effect - what I have called scientific metaphysics, and rejects the soundness of instantiating or stipulating metaphysical frameworks, entities, and posits with the intention of somehow completing the ontology of QFT:

> As to the relation between physics and metaphysics, I strongly suspect that a widespread attitude towards the significance and role of metaphysics in the foundations of physics is wrong-headed. One has the impression that some try to solve the open foundational problems in physics by inserting a sufficiently exotic metaphysical theory on top of it, hoping that the obscure (physics) and the weird (metaphysics) will happily match giving rise to some sort of physico-metaphysical. (Laudisa, 2012, 623.) magic.

I don't just strongly suspect this: I think that the tenets of scientific contingent metaphysics that respects the primacy of physics constraint demands it. Kuhlman's trope bundle account requires realism about properties as part of the furniture of the universe.

The reader might well have detected at this point that there seems to be some very close metametphysical and methodological agreement between the identity thesis approach to OSIR (introduced as H2 at §4 p27 and developed at §1.2 p36, the end of §2 p55.) I have said that Kuhlman's trope bundle approach is similar to Wayne's, but Kuhlman's *dispositional trope bundle ontology* for fundamental physics is more ontologically modest and less inflationary (Kuhlmann, 2015.) It's specifically a trope ontology, but retains this identity better than Wayne's could because of the inclusion in it of different kinds of metaphysical bindings or 'glue'. Kuhlman is committed to a careful observation of Ockham's Razor as a guiding tenet of what is very close to a scientific metaphysics, but trope ontologies commit him to tropes existing as additional particulars that are elements of the furniture of the universe (Kuhlmann, 2010a, 135.)

However, trope bundles are combinations of such property tropes taken as particulars or as being realised by particulars. This is inescapably based upon a-priorism about properties as ontologically prior, and as such it is inferior to my identity theoretic plus defeasible science based approach because it is inappropriately ontologically inflationary and in invites - relies upon - formalism driven ontic descent. In addition, were it to be deployed as a basis for an ontology of information as I am trying to do with ontic structural realism, then it would not be clear how either causality, transmission, or even source states would obtain on the basis of trope bundles and still retain naturally necessary and logically necessary information dynamical. I think it's better to constrain even French's Viking metaphysics by requiring that only those conceptual a-priori posits that can be used to model or represent contingently determined structures that obey information dynamical necessary conditions.

I take myself to be in significant agreement with French regarding essentialism about dispositions in the context of both properties and structures:

> More acutely, perhaps, on the view that symmetry principles and conservation laws play a constraining role with regard to the standard or regular laws, such principles and laws raise an obvious problem for the dispositional essentialist. Put bluntly, she cannot accept such constraints, since she holds that the laws being constrained owe their necessity to the dispositional properties that ground them and theoretical representations . . . Given the significance of symmetries (and conservation laws) in modern physics, some might take this conclusion as a form of reductio of the whole dispositional essentialist enterprise. (French, 2014, 250, 239.)

I think that it does constitute such a reductio on from a scientific metaphysical perspective. Descending ontological abstract glue and posits into the ontology from some a-priori standpoint is flawed, and I take it to be simply wrong. French wants to eliminate dispositions as a going metaphysical consideration for physics, and I think that the same should apply to trope bundles and prior properties, and to abstract binding relationships between tropes.

Arguably (obviously) something other than contingent scientific realism has been applied when one begins to speak of fields as bundles of tropes and field theories as requiring, as Wayne does, some kind of real relation to exist in the ontology to bind tropes together (the *compresence* relation), or as Kuhlman does - properties to exist as prior, or at least independently, in the ontology (Wayne, 2008, 6-7.) Neither could easily be characterised, according to the rights terms, as information sources. Additionally in Wayne's case, one could then ask what binds the identified relation to the trope, then what binds that to both, and so on in a regress of existential dependence based not upon material structure but upon a-priori posited abstract placeholders. It seems the ontological bottom or end of such posits can only be arbitrary. That doesn't just disobey Ockham's Razor as a guide to de rigeur and disciplined theorising, but simply seems to contradict the principle insensibly. Perhaps a general theory of grounding can help, but there is serious question about the status of grounding as a metaphysical posit. The debate about whether grounding has grounding or is grounded is just one indicator of this (Bennett, 2011; Chakravartty, 2013.) I do not see the point in referring to grounding, and think that existential dependence (i.e. reductive basis) is the only admissable reductive base term to include in a scientific metaphysics. As previously mentioned with regard to the normalisation proofs in QFT: mathematical machinery inflates the apparent ontology in the theory, but the terms are often cancelled out or treated as dispensible when the reference to I-ontology is considered. To retain the mathematically adduced interim and utility abstracta as I-existing or referring to I structures or dynamics is precisely what I have called formalism driven ontological descent.

A valid complaint on the basis of a scientific metaphysics is anticipated with respect to M. If we are to defer to the best physics, then it looks like M should be called real, or at least that there is adequate scientific metaphysical reason to consider it as real per scientific realism. M is understood to be indispensable to the theory of relativity, and to classical field theories and QFT. The scientific metaphysics I am proposing as correct includes deference to the defeasibility of scientific theorising, including in empirical theories. Pauli was prepared to exclude the Neutrino from the I-ontology pending experimental verification, and Barbour has argued that time does not belong in - or at least is eliminable from - Einstein's theory of relativity (Barbour, 1994.)

Rickles has summarised the purpose of theory interpretation as being about correspondence based representation in formalisms including constructed empirical theories:

> An essential part of interpretation is choosing which parts of a formalism are taken to represent something. Then one has to give an account of what they represent, i.e. one has to provide an account of the ontology. (Rickles, 2008a; See also French, 2014, 266, 268)

My overall project is to argue that when formalisms include references to *information* itself - and perhaps more importantly to signal transmission and encoding - there is a physically reducible structure with specific identifiable features (causally induced physically reducible configuration that is intrinsically semantic but alethically neutral §3.3.1 p114) being referred to. If there are any relations in the I system, and if any information is realised by relations, then it is because they are incidental to and defeasibly reduce to the physical structure of bounded regions of fields. Relations in the representing theory formalism are an encoding of information from the physical system. Information in formal theories is that which is explanatory with respect to the I phenomena, and this can only be on the basis of multiply encoded information from I sources.

Structures that don't reduce to the physical or aren't physical and causal are not information bearing: they do not involve real information. This is not a-priori stipulation, but as I will investigate in the next chapter - evident from applied mathematical information theory and a necessary requirement for the realisation of any information generation by sources and for any transmission by signals over channels.

3.4.3 Modal Innatism in the Quantum World as the basis of Ontic Structural Realism

FOSIR does not require many worlds realism about quantum mechanics to be true, and nor does it require any kind of concrete modal innatism (meaning that modality is innate to physical systems) about quantum states or their fields to be true. Steven French has proposed that the quantum world is innately modal - exhibits innate modality - due to the model nature of the formalisms and physical operators involved in QM. This not unreasonable assertion is what French points to as the existential basis for and substance of structure in ontic structural realism. French does not offer a field ontology, and does not agree with Ladyman and Ross that the universe is the totality of non-redundant statistics which constitute physical structure (although modality and frequentist outcomes do sensibly align in explantory and epistemic terms.) French does not assert a field ontology, but like Ladyman and Ross nonredundant *in re* physical statistics by stochasticity, the truth of such would arguably affect the way in which information is realised as selections of structure from the quantum vacuum/foam or totality of all quantum fields. FOSIR can in fact accommodate either proposal as the basis for field/vacuum structure - due to the defeasibility of science feature of scientific metaphysics and according to the primacy of physics constraint.

However, FOSIR cannot tolerate the substance of a structure, in accordance a field theory, being either non-physical (debates about the definition of physical - which I have in fact made an attempt to deal with at §1.2 p34 and §7.3 p252) or not *in re*. I have argued that probabilism about information conflates the measure with that which is measured: a certain category error and equivocation even in extreme cases of physico-mathematical operators. This is another outcome of formalism driven ontic descent: the measure becomes identified with the measured (§1.3 p37, §3.2.2 p87, and §1.4.1 p49.) The only way for this to be a reasonable conflation is if statistics are literally physical in the way that Ladyman and Ross assert (and it is not clear exactly how that obtains even with natural stochasticity in play), and I think that would require *all* features of formal physics to thus subsist. However, it is not clear exactly how that could be true beyond *in re* existence due to stochasticity in physical phenomena - dynamic physical processes as sources. Even if a physical realist interpretation of probabilities is true, then the old arguments about physical propensity interpretations of probabilities (among others) arguably arise (Jackson and Pargetter, 1982.)

Michael Everett and David Deutsch are proponents of the version of the many worlds interpretation of QM that is sometimes called the relative state or Everett interpretation (Barrett, 2011, 7.) According to this version, all of the possible histories that could have obtained in the universe - corresponding to all of the past possible superposition states of all of the quantum sytems in history - did in fact obtain in other entire universes. There is a different version due to DeWitt et al., 1973 that has it that a new universe is ‘branched’ or split off when decoherence or collapse of a superposition state in a quantum system occurs. In both cases the outcome is that there are perhaps infinite universes that all exist simultaneously, and none is a locus or more real than any of the others. The details of the history and variations of the many worlds interpretation involve numerous different re-interpretations and a number of different attempts to use the interpretation to prove the Born rule in quantum mechanics (Papineau, 2010a; Saunders, 2010; Deutsch, 2010; Vedral, 2010; Vaidman, 2016.)

Steven French notes that to say that the ontology of Everett and Deutsch's many worlds interpretation is "ontologically inflationary would be an understatement" (French, 2014, 194.) Yet French proposes a modalist NOSR according to which structure is *irreducibly* modal. He apparently does not require, like Deutsch, that the I-ontology - not just the ontology of theories in quantum physics and other physics of quantum scale involving statistical mechanical modelling - includes all of the possible ways the world could be (Ibid, 265; all of the possibilities) as actual and concrete (and presumably physical, although a physicalist commitment is not foregrounded or not clear.) Yet he thinks that symmetries in the physico-mathematical apparatus of QFT and quantum statistics including permutation invariance - reducing to global Hamiltonian symmetry - are inherently modal in a realist sense (Ibid, 264.)

French proceeds carefully to identify where in the representing mathematics of the formalism the innate modality exists that can be ascribed to the I-obtaining system (and French *is* interested in what in the world exists *computation* independently just as I am, but he does not state it in those terms.) He isolates permutation invariance (PI) as critical:

> Now, it is too quick to say that the kind structure of the actual world and the 'space' of physical possibilities is given simply by PI. We need both the group representations and the dynamics. The former underlie the division of Hilbert space into the relevant subspaces. (French, 2014, 266-7)

Understandably, the approach is somewhat baroque (since the mathematical and statistical apparatus of group theory and quantum probabilities are complex.) However, I think that in the determined effort to identify modality as both innate to - and ontologically prior in - the I world, and as correspondingly represented in the requisite parts of the physico-mathematical formal model and apparatus, has at least two problems. Firstly, although the mathematical formalisms are powerful, reliable, and well developed, they are still defeasible with respect to further contingent insights and improvements: if the reducibility of different elements of the formalism and its components changes then the locus of the modality might change or even dissipate (Ibid., 273-4; Although without radical findings - most of the Hamiltonian model is unlikely to change much.) Thus support for innate modality may not be available in revisable partial representations.

However, I've a Hacking-like commitment to scientific realism and representation. Ian Hacking's scientific realism is what I will call 'spray-stuff' experimentalist realism. Hacking shifts focus from theory to experimentation and deploys a kind of intuitive-cum-practical approach to realism that strongly implies both a kind of IBE and another form of experimentally centric indispensability argument:

> [W]e spray [a ball of niobium] it with positrons to increase the charge or with electrons to decrease the charge.' From that day forth I've been a scientific realist. So far as I'm concerned, if you can spray them then they are real. (Hacking, 1983, 22-3.)

This approach deploys IBE from experimentation, and because of the nature of much experimentation, induction also comes into play. Why it is a form of indispensability argument is perhaps less clear. In the case of the Quine-Putnam indispensability argument for realism about mathematical entities, it's reference in theories that is taken to constitute a sufficient condition for realism about them. In the case of Hacking's approach - it's interaction with the entities in experimental settings that constitutes a sufficient condition for realism about them.

This commitment brings me to agree with French: the physico-mathematical formalisms can be read off from our best scientific theories in this case, because they are encodings of I-information from the sources that constitute the natural phenomena. So because French presumably endorses scientific metaphysics and thus may allow for defeasibility, this first worry is not knock down. However, the second worry is more salient.

Postulating innate modality due to PI and other physico-mathematical constructs is one thing. Asserting it as being identical to the structure in the I-system is something else: if it is not regarded as defeasible. I think that French risks his own mathematical collapse - or my formalism driven ontic descent - by making the modality he identifies in the symmetries in the formalism descend into the I-ontology. French sorts through the paraphernalia of the formalism - focussing on symmetries - to pinpoint the location of the representational elements that correspond to what I have called I existent system-sources in the phenomena being modelled. He focusses on symmetries because the associated mathematical machinery captures sets of possible states for each system symmetry, and identifies actual states when terms are resolved or eliminated (a similar outcome to the cancellation of terms in renormalisation, but with different machinations.) The intensity of this worry varies to the extent that French demands specificity in the kind of modality involved.

French wrangles with the problem of symmetry breaking where it conflicts with OSR, pursuant to determining "…the grounds for attributing lawhood qua modally informed property?":

> Furthermore, PI can be considered to be inherently modal by virtue of encoding these possibilities represented by the varieties of quantum statistics, including parastatistics … So, any symmetry corresponds to a unitary or anti-unitary operator in Hilbert space … the non-negative energy irreducible unitary representations of the Poincaré group that have sharp mass eigenvalues. These correspond

> to the possible elementary states of particles ... Various classes can then be obtained: those representations for which the mass is real; those for which it is imaginary; those for which it is zero; and those for which the momentum is zero. The last do not correspond to physical objects ... The massless representations cover objects that exist on the light cone, such as photons and gravitons and also the vacuum state. Those corresponding to imaginary mass cover tachyons, which travel faster than the speed of light and thus enter into 'non-standard' causal relationships ... **the concern is that if a symmetry is broken, then it cannot be invested with the significance that the structural realist wishes to attach to it**, since the symmetry is not manifested in the relevant domain. However, instead of thinking of the symmetry as somehow 'lost', **the situation is better understood as one where the relevant phenomena is characterized by a symmetry that is 'lower' than the unbroken symmetry** ... What are the grounds for attributing lawhood qua modally informed property? Answering this takes us to the second stage and here the grounds must be broadly metaphysical, having to do with (non-Humean) reasons for taking modality to be 'in' the world rather than a feature of our theories and models, say. (Ibid., 270, 271-2, 273-4, 275)

This is where - at the last sentence - I take it that the formalism driven ontic descent is most obvious. The second bold highlight (mine) indicates an almost undeniable commitment to both ontic and explanatory reduction, but it is clear that physicalist ontic structural realism must countenance such. The idea is that "one way we can understand this idea of structure as being inherently modal—namely via the models the theory presents (cf. Brading 2011)— ... the shift of modality from those models to the world."

French must proceed to cherry-pick a particular model by way of cherry-picking a conception of model that suits his purpose. The cherry-picking is informed and coherent, but the effort is so contrived that I think this is itself an instance of French's own mathematical collapse, by way of an extended version of the same kind of conflation of *I* structure with theory dependent representation. Modalism in the mathematics has pushed back onto the *I*-ontology in a way that it seems that French should very much reject on the basis of his idea of mathematical collapse since statistics and statistical mechanics cannot be extrapolated to such *I* ontological extravagance if Ockham's Razor is to be respected. Ockham's Razor need not be respected in mathematical formal theories and in fact fecundity of posited pseudo-structures is a powerful tool in mathematics. However, Ockham's Razor is contingent for the scientific realist and for the instrumentalist since although nature is often surprising in it's structure and complexity - getting its elements wrong is demonstrably conducive to failure of scientific solutions and investigations: curing a fatal disease does not involve identifying fictional elements in the *I*-ontology unless those fictions have their role fulfilled by concreta that perform the natural function required - in which case only the latter are contingently real.

Ultimately, French has to get from modality as “a feature of a collection of [theory] models, deriving from their shared structure” to “our theories represent the [inherent] modal properties of the world” (Ibid., 277.) I think it is too quick to inflate the ontology with modal properties in this way, and that it is likely impossible without what looks very much like formalism driven ontological descent. He approaches the problem by claiming that the representing model that corresponds to the real I system is one of a range or set of possible representing models, and that the other models are all implicated as co-representing reality partially (by partial isomorphism between possible models and the represented structure) by the model that is in fact deployed to represent the actual system. This is similar to the conception of a measure of semantic information that was developed by Rudolph Carnap and Yeheshua Bar-Hilel according to which the semantic information content of a source state just *is* all the possible states (in the source alphabet or state space) (Carnap and Bar-Hillel, 1952.) This in turn is derived from Shannon’s quantitative measure, which incorporates the log of the probability of the source state calculated frequency-wise using the source alphabet probability space.

The problem, I suggest, is that this identification of modality in these other possible representing models is a brute ontic assertion inspired by mathematical contstructs, and is thus mathematical collapse - or perhaps more specifically - what I have called formalism driven ontological descent. Barrett (and Stephen Hawking) have said similar things about the many worlds interpretation of QM (which is not what French is centrally concerned with, but which would be innate modality par excellence according to his approach):

> To begin, since purely mathematical postulates entail only purely mathematical theorems, one cannot deduce any metaphysical commitments whatsoever regarding the physical world from the mathematical formalism of pure wave mechanics alone. The formalism of pure wave mechanics might entail the sort of metaphysical commitments that DeWitt and others have envisioned only if supplemented with sufficiently strong metaphysical assumptions, strong enough to determine a metaphysical interpretation for the theory. Concerning the claim that pure wave mechanics interprets itself by way of a metatheorem that Everett proved, on even a broad understanding of what might count as such a metatheorem, there is nothing answering to DeWitt’s description in either the long or short versions of Everett’s thesis. (Barrett, 2011)

French’s collapse involves the mathematics becoming the basis of the ontology: the mathematical abstracta become the furniture of the universe in that system. My conception of formalism driven ontological descent involves different abstracta being located in the I-ontology due to the efficacy of the formalism, when in fact they do not really justifiably belong there. If French’s realism about inherent modalism is not his own mathematical collapse - it looks very close. One way of stating the problem with formalism driven ontological collapse of this kind is that it begins to converge conceptually and metaphysically upon platonism about information.

In producing their measure of semantic information content, Carnap and Bar Hillel were interested in answering the pressing problem of the apparent absence of any semantics in Shannon's quantitative theory: it is by design a quantitative theory that did not treat semantic content of messages conveyed using signals as relevant, in keeping with the work of Hartley who also proceeded with the premise "[i]t is desireable therefore to eliminate the psychological factors involved and to establish a measure of information in terms of purely physical quantities" (Hartley, 1928, 536.) However, what they unwittingly embarked upon was a conception of the nature of information that predicted numerous elements of both Saul Kripke and David Lewis' modal logic and Lewis' modal realism. Kripke published "A Completeness Theorem for Modal Logic" in 1959, while Bar-Hillel and Carnap's important "An Outline of a Semantic Theory of Information" was published in 1953. David Lewis' modal logic with counterpart theory followed Kripke's work in 1968.

3.4.4 Many Worlds Interpretation of QM

The impact of possible worlds modalism and many worlds or multiverse theory upon quantum theory is marked, with numerous physicists and philosophers of physics deferring to possible worlds conceptions and characterisations of quantum systems and quantum mechanics, and of the information in quantum systems (Rickles, 2008c, 174.) Rickles regards representation in physics thus:

> I take this latter aspect [choosing what in a theory represents something] to be tantamount to the presentation of a set of physically possible worlds that make the theory true — for example, a set of individuals over which properties and relations are defined in such a way so as to make the statements and laws of the theory true. (Rickles, 2008a, 4)

Michael Everett and David Deutsch both suggest that each possible superposition state of a quantum system is real in an actual material universe based upon a model where each selection is a branch of bifurcation in the multiverse (Esfeld, 2009b; Steane, 2003.) The ontological fecundity of such a model is extreme, and I suggest that such a model cannot be accommodated by or reconciled with any pancomputational simulation model of reality because the computing power required - regardless of the computing mechanism and especially if constrained by known logics - since the computational power and required would be in the order of O^{∞} (using O notation.) The idea is supposed to be that the mathematical aptness and elegance of Everett's many worlds interpretation of the superposition states and decoherence of quantum systems is supposed to imply or even entail that there are many actual possible physical universes - each corresponding to a possible state of a quantum system under measurement (Deutsch, 1998; Rickles et al., 2006; Everett, 2012; Esfeld, 2009b.)

Lending weight to our defeasible approach to a metaphysics of information via OSIR (see OSIR.1 at §4.3 p142), however, there are other physicists and philosophers of physics that reject such assertions. Physicist Andrew Steane has asserted that scientific realism about other/alternative universes as motivated by Everettian interpretations of QM applied to quantum computation and alleged Q-Bit capabilities are not just premature, but simply a mistake:

> Quantum superposition does not permit quantum computers to "perform many computations simultaneously" except in a highly qualified and to some extent misleading sense. Quantum computation is therefore not well described by interpretations of quantum mechanics which invoke the concept of vast numbers of parallel universes ... quantum computers are not wedded to "many worlds" interpretations, not only in terms of the prediction of the results of experiments, but also in terms of insight into what is going on within the quantum computational process (Steane, 2003, 469-70.)

Since there are dissenting voices in the scientific community about the ontological ramifications of statistical QM, a scientific metaphysics that observes the principle of ontic parsimony in a defeasible manner should tend to err on the side of ontological minimalism. Since I am proposing a minimalist scientific realist field ontology in which fields are defeasibly I-obtaining and reduce defeasibly to the I-obtaining quantum field, then I have to deal with the idea (corresponding to the Everett QM interpretation) of the states of sources comprised of parts of such fields as being defined according to the configurations that do not obtain within them. The Everettian many worlds interpretation of quantum mechanics involves just such a stipulation, which makes it the same in principle and formally very close to Carnap's theory of semantic information, according to which a measure of the semantic information at a source is a statistical function of the set of states that do *not* obtain: the configurations which don't obtain. In the Bar-Hillel Carnap model, of course, there is no stipulation of I-obtaining possible universes as actual corresponding to each possible state of a source (which source does not of course have to be a quantum system.)

My approach is to defeasibly reject the Everettian approach in accordance with the tenets of the proposed scientific metaphysics - including causal closure - as involving a-priori analytic imputation. Quantum theory is one of the few scientific theories - perhaps the only one - in which such large a-priori (albeit mathematical) posits are countenanced (string theory is another example.) Rickles and other theorists have made the same observation in regards to symmetry and gauge theories (Rickles, 2008c; Healey, 2007.) Just as those theories that can be reduced are thought to contain variables that do not represent what I have called I-obtaining entities or phenomena, I suggest that the possible system states of many worlds theories represent (negatively or as alternatively encoded representations, or part of a total alternative negative representation) only the actual system structure - and not that of any real material alternative. There is no empirical verifiable evidence for the latter, and every suggestion that it is associated with subjective modelling practices. The problem is not that the many worlds interpretation of QM involves any requirement for Platonism or even Aristotelian immanent realism about structure or information: reductionist physicalism can still be the ontological naturalistic basis of all worlds. The problem is that the ontology of the statistical mechanical representing model (a collection of encoded representations) which has been encoded as a representation of the I quantum sources (structured stochastic quantum systems) has descended back into the I-ontology inflating it against Ockham's Razor. (I have called this *formalism driven ontological descent*.) The representation exists in the I world as a structured CICS based representation only.

I reject the definition of information content as being only a measure and not necessary for determining the information of a system and its structures. The latter requires CICS information only according to my approach - which I charge is closer to physics than the many world measure and characterisation of quantum information. One way to put this is that one can posit any number of possible non-obtaining configurations for any physical system as part of the representing formalism, and that one can even regard such as real on a constructivist basis: yet the actual structure and configuration do not existentially depend upon these other possibilities, and nor does its information. Another salient point is that, from a pragmatic and scientific realist perspective, if one was asked to give the information in a system and could chose between providing a representation of the actual system state or else *all* of the possible but unobtaining states, one should chose the former in order to best represent scientific practice and Ockham's Razor on a contingent basis.

3.5 Establishing OSIR and FOSIR - Some principles

In the above section I rejected both field ontologies for QFT that have significant a-priori conceptual elements and that introduce additional furniture to the ontology - usually in the form of properties as trope bundles and different kinds of logical-cum-ontological bindings between properties and bundles (among other things.) I moved to identify such ontic moves as tantamount to - or at least tending towards - formalism driven ontic descent.

The positive position I want to promote involves regarding that, contingently, acquisition and encoding of data from natural systems into representations in scientific research involves the physical extraction of information that is or reduces to physical configurations of physical structures: the *physical* information in/of the physical structures of the material world. There may be relations involved in encoding the information into representations, and there may be relations in the objective spatiotemporal causal structures themselves, but the structures are continuous in temporal and spatial dimensions as far as science can determine. Any entities identified for the purposes of modelling and representation are also heterogeneous structures. According to my naturalistic physicalist *I*-existence criteria and conception, these structures all reduce to physical causal spatiotemporal structures (CICS) and existentially depend upon and are identical to selections from heterogeneous quantum fields and or the vacuum, or else reduce to such structures. A general statement of the idea is that no representation of an *I*-obtaining natural structure can exist without the causally induced configuration of other natural structure(s), amounting to the encoding of information from the former in the latter.

Quantitative communication and transmission theories generally deal with physical information generation, encoding, transmission, decoding, reception, and processing. Quantitative algorithmic theories of information generally present measures of information in terms of numbers of structural units or the length of formal descriptions and/or atomic string objects. According to FOSIR, causally induced configurations of spatiotemporal causal structure (CICS) is both a necessary and sufficient condition for the existence of information. In this chapter I moved from a general statement of this to a specific, defeasible, contingent scientific-metaphysical statement of it, which I can now summarise thus:

> IS1: Information is (reduces to and is identical to) the causally induced configuration/arrangement of any *I*-obtaining physical structure, the configuration or arrangement of which has been caused or causally induced (via causal pathways) by some other causal spatiotemporal *I* structure(s), or to structure(s) that reduce, or at minimum supervene upon*, to such structure(s) (CICS information hereafter.)
>
> IS2: *I* structure(s) reduce(s), on a defeasible basis, to nonuniform heterogeneous regions of the *I*-obtaining quantum field.

(* The conception of supervenience that I endorse is epistemic, meaning that in-principle the supervenience base is a reductive base, but that in practice it is epistemically unavailable or inaccessible. The sources of the base are informational according to the definition herein, but out of causal or configurative reach in terms of encoding of representations thereof.)

IS1 is essentially a statement of OSIR. IS2 is a statement of FOSIR, and embodies the identity between *I*-obtaining physical structure and nonuniform regions of the heterogeneous quantum field, defeasibly.

3.6 Conclusion

Nature is the totality of dynamic causally configured structured information sources that can in relevant cases be taken to be the objects that are retained in non-eliminative ontic structural realism.

In this chapter I have developed ontic structural informational realism (OSIR), which is ontic structural realism as the basis for realism abut information via the CICS conception, along the lines of field-ontic structural realism (FOSIR.) I sought to stay close to my scientific metaphysical imperatives and premises in identifying the heterogeneous quantum field (the totality or bounded regions of heterogeneous quantum field instances and the vacuum) as the basis for the structure of ontic structural realism. This was the establishment of the identity thesis or argument.

I have argued that scientific realism about structure in nature should regard it as reducing to heterogeneous continuous fields, and that relations do not have to be - and should not be - considered to be somehow prior to structure in this context. With this approach the structural realist ontology finds support for scientific realist acceptance in classical and quantum field theories. There is no need to demand of physics and physicists that the ontic basis for structure is based upon something that they identify and use broadly in theorising: relations. Instead we can just agree with (many) physicists that fields are real and other entities and relations are embedded in them in re, are quantised from them, and exist as part of the total structure in which they inhere and which stands as either their existential basis.

I then addressed the difficult issue of the nature of causation and causality, arguing that the best deserver for providing a realist basis for the first 'C' in CICS can prospectively be realised at bottom in physical natural systems (including all of those underlying brain-mind processes and cognition) can be identified as transmissable fluctuations in the quantum field per the chosen field ontology.

I then attempted to deal with some common alternatives to ontologies for QFT and information, rejecting trope bundle ontologies as ontologically and metametaphysically misguided and inappropriately a-priorist, and as being conducive to inflation of the ontology and formalism driven ontological descent. At this stage the reader should find as (at least somewhat) original the move to eliminate relations as ontologically prior to structure (with a perhaps surprising open question about whether we can be eliminativist about them), and the ontology-reducing consequences (in keeping with Ockham's razor) of the proposed identity thesis about ontic structure and its substance as existing *in re* the quantum field and vacuum.

In the next chapter I will merge this QFT field ontology based conception of information realising structure with a source-centric (I-obtaining stochastic CICS system centric) scientific metaphysics of information that emphasises that the world is the totality of information sources, where information sources are defined according to FOSIR as causally induced configurations of bounded regions of the combined heterogeneous quantum field and vacuum.

Chapter 4

The World is the Totality of Heterogeneous Information Sources

4.1 Introduction

In the previous chapter I introduced my positive arguments for the (contingently defeasible) ontic structure to *in re* quantum field structure identity thesis/argument and the corresponding field ontology as informational field ontology (FOSIR.) In this chapter I will proceed to further associate the idea of a *source ontology* with FOSIR. I will step back a little (but not completely) from the emphasis on QFT and field ontology, and focus more upon a scientific metaphysical conception of information sources.

In this Chapter I'll argue by reference to scientific theories and their use of information concepts that are contingent and not stipulative, that the world is the sum of all stochastic *information sources*, where an information source is conceived of contingently and defeasibly as a dynamic causally induced configuration of bounded region of heterogeneous quantum fields. In following sections I will attempt to marry this source based conception of ontology with NOSR based upon classical and quantum field theory. Initially, however, I want to introduce broader metaphysical terms. I will be endeavouring to do scientific metaphysics in both steps, but initially I will be relying upon the best applied mathematical and scientific theories of information - or at least the best available applied mathematical and scientific theories that posit information and information measures - but without reference to field theories.

I'll close the chapter by discussing the deployment of contingent information concepts as indispensable in black hole physics, and then revise David Armstrong's analytic eliatic principle as a contingent principle: the eliatic information principle (IE. See §4.4 p158.)

4.2 Natural Systems are Information Sources

Ladyman and Ross see the material world as reducing to the statistical because of the enormous prevalence of probabilistic modelling and representation in quantum mechanics and information theory. However, this brings with it the problems of the nature of possibilities, of probabilities, and of mathematical abstracta (and this is true of QFT also.) If one is interested in a structural ontology and scientific metaphysics, then how these are related to information in ontic terms is something that I suggest should be addressed first. Statistics is not the only mathematised basis for reality that has been suggested: I will discuss Wheeler's "It From Bit" thesis, Tegmarks' mathematical universe, Zuse-Fredkin digital ontology, and pancomputationalism at §7.4.2 p265. I concur with a number of physcists (and claim as a simultaneous or else prior posit of my own) that the basis of the world that is the object of scientific research is configured information sources. Ladyman and Ross position that the world is the totality of non-redundant statistics is very close to this posit, since the non-redundant statistics they assert I-exist do so because they are realised by or inhere in stochastic processes. Shannon may have produced statistical models and an abstract conception of a source - but it has never followed that he thought that real sources and real information are abstracta. I doubt physicists are any different based upon the evidence of their practices and assertions about what it is that they are doing.

Natural systems are information sources. According to the definition provided by Claude E. Shannon, an information source is any stochastic physical process: anything that can exhibit either discrete or continuous changing states over time (Shannon, 1998, 1-5, 7.) Shannon (and following him, philosopher Fred Dretske) model such sources statistically, and base their conception of information largely upon statistical measures of such physical processes. However, statistical modelling of such entities in reference to information is optional, and not necessary – nor even appropriate - for a foundational conception of information. More fundamentally in metaphysical and physical terms, a source is any entity (including any natural system) which has spatiotemporal structure or structure that can change over time, and which can causally interact with other physical structures in the environment (Barbour, 2015, 5-6.) This is the basic reductive conception of an information source according to CICS.

Some philosophers, notably Jaegwon Kim, have suggested that comprehensive descriptions of physical systems are in principle available qua ontological reduction (Kim, 1999, 129-30.) This is the assumption that a continuous natural system is ideally comprehensively reducible in terms of its physical structure to constituent information bearing subsystems, mechanisms, processes and other constituents and microconstituents. Sandra Mitchell argues that Kim's thesis against irreducibility and emergence relies upon the use of a "privileged level of description in which all levels of complex structure and behaviour can be restated and thus reduced." (Mitchell, 2009.)

It is not clear whether Kim thinks that objective descriptions exist in the world prior to the measurement and observation of physical systems, or if the assertion that there are universal descriptions is just a statement about all systems being ideally contingently describable. If the former is the case, then Mitchell's complaint is well founded, since such information-bearing descriptions would have to exist somehow as real abstract entities prior to being encoded as such from the information in the physical system(s.) As an a-posteriori *in re* realism that is not ascriptivist – does not see descriptions as information but as encodings of information – CICS precludes this ontological a-prioricity of descriptions.

The scientific metaphysics of information that I am presenting calls into question whether any kind of description or formal representation - lexical and constructed or else somehow platonic - can ever be complete, even if it the non-platonic option involves simulations and diagrams, with programmatic/algorithmic elements, and not just linguistically expressed or logically regimented descriptions. I suggest that a truly comprehensive representation of a continuous system is practically impossible if comprehensive means all of the information in the system where information is regarded as realised by the spatiotemporal structure of the system (Gillies, 2010 1-2, 7-9, 17.) This still holds if physics does in fact (defeasibly) bottom out at the quantum field and its vacuum state(s.)

4.2.1 Configurations and Sources

According to Julian Barbour, a configuration – which can in many cases be represented mathematically as a point value in a mathematical configuration space associated with the physical system - is a valid information source. It is essentially "any structured thing", and information is the distribution or arrangement of physical parameters and attributes such as "colours and shapes" that can be observed in such structures (Barbour, 2015, 4.) Barbour's conception of configuration is very specific to the idea of time capsules as expounded in his 1999 The End of Time. It very closely resembles Dretske's indicator semantics conception of nested information in the configuration of the rings of a tree (Dretske, 1981; Dretske, 1999, 108,121.), and this concept is essentially that put forward by Dennis Stampe and Fred Dretske in their attempts to provide a causal-indicative theory of semantics and an naturalised informational epistemology respectively (Stampe, 1977, 48-51; Stampe, 1986, 128-32; Dretske, 1981; Dretske, 1988a; Dretske, 1995;) This conception of semantic content via signal as an indication of past states of systems - causally transmitted - has origins also in H.P. Grice's conception of natural meaning (smokes indicates/means fire) and Saul Kripke's concept of a causal chain of reference (Grice, 1957.) Leibniz provides for Barbour his "central idea" of a configuration as an a-temporal instant : a 'snapshot' of the total material arrangement and state of the universe (Barbour, 1994, 16.) It is associated with "the general notion of an instant , which is identified with a possible configuration of the universe" (Barbour, 1994, 2854.) The configuration – the structural arrangement of the instant – carries semantic information from the conditions and nomic constraints that produced it:

> I claim that the configuration carries intrinsic semantic information in the sense that different intelligent beings can in principle deduce the law or process that explains the observed structure ... and intrinsic semantic information, which distinguishes a random message, or configuration, from one that carries meaning and to some extent explains its very genesis (Barbour, 4,5,9.)

For Barbour, the universe is not the only configured time capsule. Other examples are complex physical systems – subsystems in the universe - like human brains and the earth itself (Barbour, 1994, 33.)

Barbour's conception of intrinsic semantic information coheres with Dretske's adaptation of H. P. Grice's natural meaning for the intentionality of information content (Dretske, 1981.) Dretske defines the intentionality or intentional content of the information content of a specific signal transmitted from a transmitter physically connected to an information source (using Shannon's conception of a source as a stochastic physical process) as being the physical source that caused the signal. This is the physical entity or system that is causally linked to the signal. Say there were two sources – A and B - which were perfectly internally identical in terms of their spatiotemporal configuration, and each causes a separate signal – C and D respectively - that were likewise perfectly isomorphic in terms of spatiotemporal configuration. The intentionality of the information content of the spatiotemporal structure of signal C can only be the source that actually caused it: source A (Dretske, 1981, 75-76.) Grice's natural meaning is often illustrated with the example of smoke and fire: smoke means fire because fire causes smoke according to nomic natural constraints and conditions. Therefore, smoke carries an indication in its configuration of the nature and structure – the configuration - of its cause.

The semantic content of information realised by spatiotemporal configurations is very similar in its realisation to the meaning of what C.S. Peirce called a reagent sign (Peirce, 1895-7, 17.) Peirce used the example of a weather cock such that the physical position of the weather cock with respect to its possible positions gave an indication of – and thus information about – the nature and properties of the causal physical structures causally acting upon it. The semantic content of some information according to CICS is what it indicates about the dynamic spatiotemporal structures that realised it and that influence or configure it. No conception of reduction in subjective or objective uncertainty or enumeration of non-obtaining or counterfactual possibilities is required.

In the molecular biosciences, the idea of casually induced spatiotemporal configurations of molecules in protein folding is regarded as constituting part of the information of the system in at least two ways. Firstly there is the functional-causal (teleosemantic/infotel semantic) information of the molecule structure as transmitted from causally upstream RNA and DNA - very much a CICS-source compatible conception:

> Melkikh (2013) discussed the issue of complexity with regard to biologically important molecules. If we consider replication as a catalytic chemical reaction, in which the complexity of biomolecules

> plays a critical role, this process can be divided into two stages: folding the molecules into the native configurations and recognizing the molecules when making copies. Most biologically important molecules (primarily proteins and RNA) have only a small number (typically one) of configurations in which these entities function. What, for example, will a copy of an RNA molecule look like? Generally speaking, this molecule can fold into a variety of potential spatial configurations. If these configurations are different from the original configuration of the RNA, they are no longer copies; RNA in another configuration represents another material with completely different characteristics . . . A large number of reactions between two interacting molecules are possible. Many chemical reactions (including those associated with the transfer of information) involve a "key and lock". . . mechanism, under which the shape of one molecule must precisely correspond to the form of another to permit enzymatic reactions... Currently, these mechanisms are considered as modular blocks when existing genetic units are used again for the new encoding species; however, this algorithm implicitly assumes that the genetic system contains a priori information about optimal combinations of nucleotides. This information should be mathematically included in evolutionary theory via partial-information games. The storage of such large amounts of additional information might be explained using quantum mechanics. In principle, qubits store an exponentially large amount of information, although only for pure quantum states, and the question arises of how to avoid decoherence in this system. (Melkikh, 2014, 34. See also Sarkar, 2005, locations 182-186.)

Then, after transcription and translation from DNA via RNA and ribosomes, there is the set of possible functional configurations of protein molecules (causally induced with the assistance of chaperone molecules and more ribosomes.) There are many possible denatured states of a protein (non-functional disordered states) and a much smaller number of functional *native* states. Then there is the abstractive, encoded representing configuration of the phase space that is used to represent and map/track the evolution of the protein folding process and system (itself a dynamical source). Then there's the abstractive encoded representation of the energy landscape that is used to model the relationship between the energy of each conformational configuration of a molecule and its free energy (or the energy required to get it to a fully folded state) in protein folding (Wolynes, 2008; Onuchic and Wolynes, 2004, 70-3; Fang, 2015; Sasai and Itoh, 2009, 2-3; Dill et al., 2007, 344; Dill et al., 2008a, 292, 296; Biro, 2013; WEISS et al., 2000; OŁdziej et al., 2012.)

Melkikh's work is an excellent example of scientists doing contingent metaphysics of information using a conception very much like CICS hybridised with classical information theoretic notions and Sarkar-style conformational-structural information components (Sarkar, 2005; Melkikh, 2014, 4.2.1, 42.) It includes defeasible speculative considerations based upon actual scientific practice with, and corresponding findings about, protein folding dynamics. I suggest that protein folding studies in molecular bioscience (see especially the references cited in the previous paragraph) provide strong support for my indispensability argument (Intro. §1 p16 and Intro. §3 p28) based upon references to information, structure, and configuration of structure in the special sciences.

4.3 Stochastic Sources Have Ontic Priority Before Statistics

Like Ladyman and Ross, I am seeking an NOSR that accommodates scientific realism on a structural realist basis, such that realism about *I*-obtaining structure is preserved along with tolerance for defeasibility about the content or essential nature of the structure(s) assumed to be the target and subject of representation in empirical and formal scientific theories:

> Metaphysical commitment that we think structural realism ought to entail . . . is that there are mind independent modal relations between phenomena (both possible and actual), but these relations are not supervenient on the properties of unobservable objects and the external relations between them, rather this structure is ontologically basic. This is enough to make structural realism distinct from standard realism but also from constructive empiricism. From this metaphysical thesis there follow plenty of realist methodological and epistemic implications but, we hope, no unsustainable beliefs in the specific ontologies that are employed to help us grasp the structure of the world according to particular theories. (French and Ladyman, 2003b, 42.)

I am rejecting modal realisms about structure as part of the analysis in OSR, and in so doing forestalling moving from the classical model of information theory with its alphabet of possible source states, via statistical mechanics in QM with its sets of representations, to an uncalled for realism about the possible states and representations that contravenes POP and constitutes formalism driven ontological descent. Alleged innate modalities of the kind endorsed by French and of the related but different kinds endorsed by Deutsch and Everett don't make into FOSIR. The CICS of FOSIR is not modal (although since information sources are stochastic processes - it is statistical in the sense of being stochastic.) Models representing it may be, but it does not follow that we must allow it to descend from the representations of the model into the *I*-ontology.

My further revision is the elimination of relations as the necessary foundation of structure. Structure as a ontic basic of which relations are a feature and not the basis. This kind of revision is not foreign to discussions of OSR. For example Floridi - in developing his object retaining ISR - establishes that some relata are not prior to some relations, and regards relations themselves as structures:

> Relations (structures) require *relata* (structured/able objects), which therefore cannot be further identified as relations (structures) without some vicious circularity or infinite regress. Yet this is precisely what OSR appears to be forced to argue (Floridi, 2011c, 353)

According to my approach, the defeasible and contingent ontological basis of structure is just I-obtaining fields. In fact, structure is intrinsic to fields at bottom as physical patterns or within the fields, and all other non $I-i$ structure reduces to and derives from such. Relations are picked out of such fields on the basis of mathematical encoding of features from I-structure (see also Rickles, 2008b.) Relations are instrinsic to structure according to this approach, but structure does not existentially depend upon relations.

Ladyman and Ross have gone on to further develop a probabilistic NOSR according to which statistical and/or statistically inferred structure is at the ground floor of the ontology:

> We build our rhetorical bridge by beginning with a famous philosophical slogan of Wittgenstein's that many scientists will know... 'The world is the totality of facts, not of things.' ... We here adopt the form of address ... to state our metaphysical thesis: the world is the totality of non-redundant statistics (not of things.) (Ladyman and Ross, 2013, 146-7.)

According to their approach a scientific metaphysics points to statistics as the effective bottom of the ontology. I do not even agree with this being the best choice defeasibly, let alone that it is entailed somehow by IBE or induction. It is in fact non-contingently metaphysically loaded (albeit it very subtly) by dint of being an example of formalism driven ontological descent - and that's with the understanding that Ladyman and Rosss conception of probabilities is physicalist and that they I-obtain, and that there is nothing inherently problematic about that finding according to their scientific metaphysical approach. FOSIR also allows and in fact requires it. However - returning to the metaphysics of information - I identify what I suggest is a more satisfying ontology: the world is not the totality of non-redundant statistics, but the total set of both stochastic (Gray, 2011b) CICS information sources (or physical dynamical systems.)

My conception of ontic structural realism is best described as non eliminative physicalist ontic structural informational realism (Ontic structural informational realism.) Objects are retained as structured entities and these are information sources, which are arbitrarily bounded field regions or regions of the quantum field. They include stochastic and non-stochastic processes and dynamical systems. This component of the ontology is influenced by the applied scientific and applied mathematical quantitative and algorithmic theories of information of R.V.L Hartley, Claude E. Shannon, Andre Kolmogorov, and Alan Turing (Zurek, 1990a, 2-4; Ehrenfeucht et al., 2012, .) Moreover, quantum information scientists and physicists regard information as something that is only realised by physical structure (Landauer, 1999, 63-7; Floridi, 2003) [1].

My own ontic structural informational realism Ontic structural informational realism (to be distinguished from Floridi's ISR) has a different ontological basis to that of French, and to that of Ladyman and Ross:

> **Ontic structural informational realism.1**: The world (the set of real things/stuff) is the set of all stochastic CICS information sources.

Ladyman and Ross have - despite best intentions - produced an (albeit physicalist-realist) instance of mathematical collapse. This is not because their claim that statistics I-obtains in stochastic systems is vacuous. Especially in the case of frequentist data sets and in all dynamic physical systems. It's instead because they decide to establish stochasticity - presumably undefeasibly - as the in-principle stopping point for scientific metaphysics. This seems to contravene their own stated goals.

Technically - embracing the distinction between mathematical and statistical as Ladyman and Ross recommend - their posited ontology involves not mathematical collapse so much as statistical collapse in that the arbitrary stopping point for ontology has become stochasticity (aptness for statistical modelling, and exhibiting statistically analysable patterns) and is perhaps even computational. It very much appears to be physico-statistical or physico-computational, but there does not seem to be any scientifically motivated reason for not offering an explanation of this (a reference to frequentism and/or physical entropy for example) beyond the obervation that quantum systems are apt to be statistically modelled because of their stochastic nature.

If it is the stochastic nature itself that is being referred to as the nonredundant statistics, then it would seem redundant to mention statistics at all, and it would seem that I-stochastiticy is all that is being picked out. This is much closer to my view than the idea that nonredundant statistics is the content of structure. However, given debates in QM about how and in what way quantum systems exist probabilistically - what the ontological import and entailment is - it is not clear that stopping at stochasticity can be any more than a defeasible approach, or even consistent.

Ladyman and Ross's justification is also what is supposed to avoid French's "mathematical collapse". Statistics is distinguishable from mathematics as being part of the I-obtaining world and its I-ontology:

> This is indeed the impasse that some of our critics (e.g. Dorr, 201 0) allege us to be stuck in. Structural realism, they say, in principle lacks resources for being able to distinguish pure formal structure from empirical reality, and turns into Pythagorean idealism. Mysticism is clearly not what most naturalists would regard as a happy final refuge. However, there is a more plausible alternative

[1] Also (Barbour, 2015, 1, 3-4); (Di Vincenzo, D. P., & Loss, D., 1998); (Bennett & Landauer, 1991, 1985, 48, 51.);

> that doesn't lead in this direction. The fundamental empirical structure of the world is not (p.148) mathematical but statistical. And there is no such thing as purely formal statistics. The 'principles' of statistics are simply whatever dynamics emerge from our collective exploration of, and discovery of patterns in, data. (Ladyman and Ross, 2013, 147-8.)

It's pretty clear that - even putting subjectivist and Bayesian interpretations aside - the principles of statistics come from other places also. I agree that nature is intrinsically stochastic in the sense that the changes in states of dynamical processes can be treated statistically and are thus stochastic. I also agree that stochasticity is not dependent upon mathematics - not mathematical abstracta anyway. However, there is arguably a distinction to be had between what is stochastic and the statistical, or statistics. The former is I-obtaining according to Ladyman and Ross, the latter is probably computation and mind dependent, unless the implication is that the I-system is apt for modelling by formal statistical constructs. Ladyman and Ross, however, regard the origin of these constructs from a constructivist perspective. Put otherwise they are encoded representations of patterns in I-frequency data. Otherwise the mathematical structure has descended into the I-ontology illicitly.

The structural realism Ladyman and Ross develop is scientific realist, but in a different way completely to that endorsed by most reductionist physicalist scientific realists, which approach fits with the rejection of a certain kind of reductionism. The problem seems to arise, however, that they regard the physical I-ontology as real on the one hand, but on the other hand as not just only defeasibly accessible but apparently effectively eliminable:

> However, as d'Espagnat (2006) points out, nobody has proved a version of Bell's theorem using only locality and not some form of realism, or counterfactual definiteness about unperformed measurement results. D'Espagnat himself is sympathetic to a Bohrian or neo-Kantian version of structural realism. He argues that quantum physics undermines not metaphysical realism, but any confidence that we are able to grasp the ultimate 'ground of things' (see especially 2006, Chapter 1 9); we would strengthen this by denying that there is a convincing basis for believing there is any such ground. (Ladyman and Ross, 2013, 136.)

Their later assertions seems to revise this, since irreducible stochasticity and the totality of nonredundant statistics seem to necessarily be what they propose as the I-obtaining ground of nature. However, Ladyman and Ross are claiming that a reductive bottom of the ontology is not as significant as supervening Dennettian real patterns, and that these are identified by statistical constructs, with which high degrees of predictive success are associated in such disciplines as QFT. Moreover:

> However, the Everett interpretation, while not revisionary physics, is (naturalistic) metaphysics, in that it unifies theories indispensi-

> ble for predictive success, but contributes no novel predictions itself. Our point is only that an alternative unifying metaphysics is available. This involves denying that there is any real causal process corresponding to wave function collapse, and hypothesizing that the statistics directly identify the relevant real pattern—that is to say, a basis for prediction that supports all relevant counterfactuals and is non-redundant in the specific sense that no 'deeper' pattern—Everettian or otherwise—supplants it. (Ladyman and Ross, 2013, 137-8.)

The implication is that the physical I-ontology does not exist and only statistical structure is to be had: there is no reductionist bottom, except stochasticity, with no apparent need to countenance the I-existence of what it is that is stochastic. This latter possibility does not fit with Ladyman and Ross's other statements of realism about I-physical structure.

However, Ladyman and Ross clarify that they are scientific realists about I-ontology and elements of the formal theoretic representation thereof, as secured by statistical modelling, but regard that the ontological details are out of reach and that all that is in reach is statistically adduced patterns:

> In the framework of dichotomous opposition between standard realism and standard instrumentalism, wave functions and utility functions—along with countless multitudes of similar devices used across the sciences—are liable to be regarded as 'pure formalism'. But this fails to do justice to the ways in which they are embedded in theoretical and experimental contexts that are rich in ontologically robust structure. Even in the most abstract reaches of formal science, where the only objects of manipulation are representations of functions or elements of topology or high-dimensional sets, there is always ontological commitment to the data and their statistical structures. (Ladyman and Ross, 2013, 139.)

So although the world is the totality of non-redundant statistics: those statistics are realised by I-structures. This seems to be very much an explanatory reduction with ontic commitments (i.e. An ontic-content reduction.) I agree with Ladyman and Ross in avoiding admitting modality into the ontology in the manner that either French or Deutsch do. However I also think that their ontology is confused in the sense that they propose a conception of a ground of nonredundant statistics that is non-reductive (irreducible stochasticity) yet involves admission of ontological commitment to data and statistical structures that are taken to be innate to the I-existing system as a kind of content. I simply bite the bullet on the ontic content being supplied (defeasibly - but accordingly fairly and increasingly reliably) by the quantum field and random vacuum, and dynamical regions thereof regarded as information sources. As Ladyman and Ross say, "the world is stochastically structured", but it is not clear that pushing statistics down into the I-existing ontology - even as dispositions or natural frequencies (Ladyman and Ross, 2013, 145) is not a kind of formalism driven ontological descent that makes statistics the bottom of the ontology when perhaps stochasticity should instead be regarded as an ineliminable feature of all natural I-obtaining information sources. Shannon's information sources are literally physical stochastic processes, but they're stochastic processes, not processural stochastics: the stochasticity is a (probably ineliminable) *feature* of the structure. It's concrete physical information sources realised defeasibly as heterogeneous structures reducing (defeasibly) to the heterogeneous quantum field that constitute the world in its totality. Not just bare structure somehow, and not just statistics in terms of irreducible stochasticity, but information sources.

4.3.1 Quantum Field Theory and Bounded Field Regions as Information Sources

According to this approach bounded regions of heterogeneous nonuniformity in the universal quantum field. The main point of difference with existing physicalist field ontologies is that I question the nature of relations and see them as existentially dependent upon nonuniformities in the microsphysical structure of the quantum field, rather than the basis of that structure.

A standing debate among ontic structural realists has been the relationship between relations and objects as relata (Esfeld, 2004, 602; Chakravartty, 2004, 152; Cao, 2003c, 3; Rickles, 2008b, 20.) Mauro Dorato has observed of relations in OSR that "I daresay that no ontic structural realist should be falling into the trap of accepting the view that "relations can exist without relata"" (Rickles, 2008b, 21.) I agree, but I have eliminated relations as an ontological ground for structure, and instead regard relations as partial information that can be picked out in an I structure:

A. Objects/entities as relata can and have been regarded as reducing to (micro)structure(s), and

B. Accordingly, (micro)physical structure(s) reduce(s) to other (micro)physical structure(s), and

C. Instead of assuming that B. means that A. must be incorrect somehow, we should instead accept that

D. Not only do (micro)physical (micro)structures not reduce to relata, but additionally

E. (Micro)physical (Micro)structures do not reduce to relations, but physical relations are simply features of physical structures

F. Structures in microphysical systems reduce to classical fields and then quantum field regions.

Otherwise, I suggest, we are inviting mathematical collapse and ontological descent from the start by making features of structure picked out for formal and epistemic reasons (in line with instrumentalism) the ontic necessary condition and ground for the I structure being modelled in the first place. I suggest that if one wants to be a scientific realist, then that is not the way to go about it. So the overall strategy is to eliminate objects *and* relations both from the ontology *as existential grounds or the reductive basis* for physical I-obtaining structure (see my comments about something being wrong with the existing picture: §3.3 p101.) My adjunct ontological move is to assume that there are three kinds of relations in the broad ontology of the empirical theory:

1. Real physical relations that exist in microphysical structures, not as the existential basis of those structures, but only as incidental and intrinsic to them

2. Applied mathematical relations that encode part of the information from such structures in mathematical structures.

3. Pure mathematical relations that can map to applied mathematical relations and do not have to have any correlate in the physical world

The primary distinction between (2) and (3) is that (2) is contingent and a-posteriori, whereas (3) is arguably only a-priori (although that is open to debate on mathematical intuitionist grounds, and according to the tenets of The Canberra plan which regards theories, models, and hypotheses as contingently informed.) There is no a-priori or a-posteriori knock down argument that (3) are the ontological basis of (1) and (2) or prior to (1.) In fact (1) seem to be possible without any reference to (3.) That is, in keeping with the theme of avoiding the problems of the ambiguity that arises from dual definitions of phenomena and entities in empirical theories, which I discussed in previous sections, I separate out the ontology of the theory and its mathematical expression from the I ontology. This move is not unusual (French, 2014; Rickles et al., 2006; Cao, 2003c.) The three together are what I have called the *broad* ontology of the empirical theory.

(1) simply means that neither relata regarded as objects nor relations are the existential basis of structure, but that structure is the ontological primitive and entities/relata are in fact arbitrarily bounded substructures and relations between them are incidental to picking such structures out - albeit based upon their remarkable natural kind features. Functional or physically causally non-inert relations reduce to structure or the configuration thereof and so called intrinsic properties reduce to the configuration and constitution of the structure.

Cao provides a good summary statement of the standard non-eliminative ontic structural realism idea that relata emerge because of relations that form the basis of structure:

> It was further argued by some structuralists that in terms of human access no intrinsic properties of an entity can be shown to exist at the fundamental level. ...physical properties can only be identified through the relations they are involved in; but identity of relations does not imply identity of intrinsic properties. So we can

> never know the properties of physical entities in so far as they are intrinsic. Here we are getting closer to a pure relation ontology, in a sense that the relata exist but they are constituted by the relational structure in which they are embedded, which in turn provides a ground for structuralism. (Cao, 2010, 210)

I am instead rejecting a pure relation non-eliminative ontic structural realism ontology, with the intuition that hard science, and specifically QFT, defeasibly point to a different ontological reality: relations are selections of informational structure from a total structure. The structure is ontologically prior in the strong sense that if you ignore any 'picked out' relations the structure still exists, and if relations are instrinsically part of the total continuous structure and its information (see my earlier multiple/partial wireframe argument §2.3 p62) then they are just that - only part of it.

This is a very significant difference in my approach to ontology with scientific metaphysics. Causal intrinsic properties reduce to and existentially depend upon the composition (heterogeneity) and configuration (nonuniformity) of the structures which existentially depends upon and reduces to the nature and configuration of I fields. It is the causally induced configuration which constitutes the information. Contrary to the common approach to abstract metaphysics and modelling - I am brute asserting the following identity: bounded (including distributed complex) regions of I-obtaining fields are identical to structures I-obtaining in the system. Any non I-obtaining structures in the formal representing empirical theory - which I take to be constructed on an intuitionist basis and an a-posteriori construct of the formal representing theory - exist only as an encoding of the information of the I structures [2].

Another way of putting this is to say that intrinsic relations are abstract features of - by way of being I-obtaining information selected from - substructure(s) of non-uniform structure(s) that are identical to nonuniformly configured heterogeneously comprised I-obtaining fields. Relations in the theory that are not I-obtaining in the system being modelled still reduce to I-obtaining structures, but there are complexes of many different sources and encodings therefrom: brain based information processing and encoded formal lexical descriptions, for example. Configuration of trajectories in phase spaces representing the evolution of dynamical physical systems are also intrinsically informational, but they encode information from the physical systems they represent. Redundant or overdetermining extended phase spaces in quantum physics may still be regarded thus as encodings, but the encoding processes are arguably more complex.

The relations in (2) could be taken to be the existential basis of mathematical structures which they apparently specify, define, or participate in - although I do not see why this should be a necessary condition for the existence of mathematical structures. Even if it is, I reject that existential reduction

[2] I agree with Rickles on this point, except for his subscription to modal many worlds interpretation of QM which I take to invite formalism driven ontological descent Rickles, 2008b, 4

to and dependence upon relations is a necessary condition for the existence of (micro)physical structures.

That is - relations in formal theory structures are largely mathematical projections onto physical structures (including the physical relations in them) that help scientists pick out relevant features of such structures in order to analyse and model them. Pure mathematicians and theoretical physicists can happily do mathematical work with mathematical relations as a way of modeling abstract structures. Applied mathematicians and physicists can do this too, but I suggest that *it does not follow that the structures of the physical world that are modelled using relations actually reduce to relations.*

Another way of saying this is to subscribe to the defeasible structure-field bite-the-bullet identity thesis that I have proposed: that structures are just are and/or reduce to nonuniform physical fields - or in the case of the microphysicalist reductive approach nonuniform/nonuniform regions of the universal quantum field. This seems like pedantry from a pragmatist perspective. However, I have already demonstrated why physicalism about information is not token physicalism, and not nominalism. When it comes to information we are beholden to different ontological standards with respect to reduction and explanation because a metaphysics of information is self-reflexive and metametaphysical: we cannot use notional terms or abstractive handwaving, nor supervenience, to explain information in terms of information (as we might explain explanation, knowledge, or meaning in terms of information.)

The reductionist physicalist approach to the nature of information means that intrinsically representational/semantic CICS information reduces to microphysical structures in all cases. Our starting point for a non circular explanation of the nature of information is something like that given by Esfeld's statement of physicalism as reducing conceptually and theoretically to microphysicalism:

> Ontologically speaking, we assume that macroscopic systems are composed of microphysical ones. It therefore makes sense to characterize physicalism in such a way that it is microphysics on which we should focus. The claim then is that everything that exists is something microphysical – in the sense that everything is realized as some sort of a microphysical arrangement. No one maintains that our current microphysics "is the measure of all things, of what is that it is, and of what is not that it is not." But the idea in physicalism is that our current microphysics is on the right track to discover the truth of the matter. (Esfeld, 1999, 319-20)

I think that the natural move for a structural realist physicalist scientific metaphysics has been indicated correctly by Ladyman and French:

> The kind of structuralist moves we have outlined here have also been powered by the development of field theory. Cassirer, again, argues that the metaphysical view of the 'material point' as an individual object cannot be sustained once we make the transition to

> field theory (op. cit., 178.) He offers a structuralist conception of the field: The field is not a "thing"; it is a system of effects (Wirkungen), and from this system no individual element can be isolated and retained as permanent, as being "identical with itself" through the course of time. The individual electron no longer has any substantiality in the sense that it per se est et per se concipitur; it "exists" only in its relation to the field, as a "singular location" in it. (ibid.) (French and Ladyman, 2003b, 46-7)

Although I am not a physicist, I am fairly certain that "singular location" is not a very apt description here. I suspect that descriptions like "structured region" or "structured feature", or perhaps "emergent substructure" or "emergent configuration" of a substructure, would all be better characterisations. Otherwise I think that this view provides solid support for FOSIR including its defeasible structure-is-quantum-field-regions identity. Michael Esfeld and Vincent Lam have articulated a nice summary of French and Ladyman's 2003 position regarding the utility of a physicalist field ontology:

> However, there are in fact strong reasons in favour of a field ontology on the basis of quantum field theory: the notion of a quantum particle, with all its physical content, can be derived from the primary notion of a quantum field and is actually not always well-defined (see Cao, 2003c, pp. 17–19) Esfeld and Lam, 2008)

In a survey of work on field theory as a basis for structural realism by Cao, F&L identify a defeasible and ontologically parsimonious and/or minimalist non-eliminative ontic structural realism as that which will work with fields in mind as the ontic reductive basis of the world:

> Furthermore, and crucially, given the rejection of particles as the basic ontology in QFT, it seems to us that the sort of developments Cao very nicely charts provide powerful support for the metaphysical SR programme. In particular, he asks about the reality of quantum fields and responds that the concept of a field is used to generate the field equations which describe the structural aspects of "these hypothetical entities" and to 'extract' the concept of particle which are the 'observable manifestations' of the same hypothetical entity. But then . . . what is this 'hypothetical entity', over and above the structural aspects? What is it, metaphysically? Here, again, we face . . . metaphysical underdetermination . . . Now, as we have said, the constructive empiricist responds to this by waving good-bye to metaphysics but what is the realist going to do? Again, its an ersatz form of realism that can't answer - in these terms - the question, what is the field? SR has an answer - the field is the structure, the whole structure and nothing but the structure. (French and Ladyman, 2003b, 48)

My view - my answer to the metaphysical underdetermination of the type or natural content of ontic structure in OSR and field theory - is that the structure reduces to heterogeneous bounded (including distributed) regions of the (quantum) field. To look for any other substance or intermediary is to start instantiating anti-POP 'glues' and abstracta that are not real, or else real only as encodings of information from sets of I sources. I bite the bullet, reject formalism driven ontological descent, and just declare that not only is the structure physical as F&L declared (French and Ladyman, 2003b), but that it just is the heterogeneous quantum field. It is partly in agreement with F&L's stated view in so far as it supports OSR. However, it is the inverse or antithesis to the view in that it privileges I fields as the ontic basis of - identical to - structure and ontologically prior to it but not determined by mathematical relations and models. The nonuniform heterogeneous quantum field comes first, and it is intrinsically structured. The structure does not somehow come first as an ontological basis for the existence of the field, a position closer to that of Cao and French's later 2014 view. Ladyman and Ross instead embrace a statisticalist view in deference to instrumentalist themes.

My approach allows for partial representation on the basis of information access problems, but bites the bullet on the physical I universe being the origin of structure in physical information processing, and thus in brains, and thus in mind and thought. The cognitive science or philosophy of mind that accompanies this can be simply stated: the mind is identical - not to the brain and its states - but to the physical processing of physical CICS information in the neurology regarded as a CICS information source (For similar if not supporting views see Deutsch and Ladyman and Ross Ladyman and Ross, 2013, 120.) Brain based representations naturally necessarily can't exist without brains, and brains naturally necessarily can't exist without I-obtaining physical information processing and signal pathways. The signal pathways must necessarily exist prior to the information transmission. Signal pathways must necessarily be causal. Encoding is supported by rules, but reduces otherwise to transduction of various kind (a significant proportion of which is electro-chemical.)

There is no reason to assume that there would exist any mathematical and formal structures without brains and the physical information processing based cognition that they support. Perhaps we might concede that probabilities are natural and I-exist as Ladyman and Ross require, or that lines and surfaces do. However, it would not be uncontroversial to refuse to admit the latter, given the well known debate about physical points, and geometrical primitives and ratios are one thing, but complex mathematical structures involving such things as complex numbers with imaginary components, or entire proofs or formulae, do not seem to be something easily admissible to the I ontolgy as prior at all (Malament, 1982, 528.) Thus it is ontologically unparsimonious - contravenes POP and possibly causal closure - to assume that mathematical structures are existentially transcendental. They may be apparently or virtually transcendental because nomic and logical constraints such that if aliens discovered them somewhere else independently of humans they would end up similar (the mathematical constructivist view.) However, it does not materially or logically follow, and it is against POP, to assume causal I a-priori existence of mathematical structures: certainly to give them an a-priori causal role. Nomic constraints related to logical/analytic truths do not constitute sufficient conditions for a-priori existence of such either. Statistical mechanics as we know it might be universally applicable to modelling the I structures of quantum systems, but so are several other mathematical systems that we know of, and so might be many others of which we are not aware. In the face of such overdetermination, claims of mathematical structure as a causal existential basis for I structures of finite physical systems seems ontologically unparsimonious at best, and moreover, contradictory. FOSIR gives a place to Kolmogorov's materialist constructionist view - although perhaps not in its strict Brouwerian intuitionist format. I do not have to secure either here.

4.3.2 The View from Black Hole Physics

Especially in cosmology and broader physics, conceptions and characterisations of what is usually called information are closely related to and associated with physical and physico-mathematical concepts like entropy and complexity, each of which also seems to be inherently concerned with physical processes and their structures. And apart from such things as mathematical overdetermination in gauge symmetry and intermediate mixed states of quanta in QM, in physics these theoretical concepts are intended/taken to correspond to physical existents: they are scientific realist assertions about information. Moreover, in physics - the foundational hard science - the term information is closely conceptually bound to various concepts of physical structure(s) and the movement thereof. One example is the attempt to solve the problem of what has come to be called the information paradox in relation to the science of black hole cosmology:

> Black holes are, however, plagued by fundamental paradoxes that remain unresolved to this day. First, the black hole event horizon is teleological in nature [6], which means that we need to know the entire future space-time of the universe to determine the current location of the horizon. This is essentially impossible. **Second, any information carried by infalling matter is lost once the material falls through the event horizon**. Even though the black hole may later evaporate by emitting Hawking radiation [7], the lost information does not reappear, which has the rather serious and disturbing consequence that quantum unitarity is violated [8]. (Joshi and Narayan, 2014)

My argument is that in such theories 1. references to information are just as indispensable as references to structure and 2. references to information carry the same physical content as references to physical dynamical structures and are often associated with them.

Hawking's revision of the classical model of black holes to accomodate radiated heat and emitted information relies on the nature of what was previoulsy thought to be a perfectly smooth event horizon boundary now being understood as irregular and 'fuzzy' (or 'hairy'.) Black hole physics is replete with informational language which directly associates ideas of the distribution and structure (especially complexity) of matter and energy inside the black hole and across the actual or else apparent event horizon with the distribution of information:

> The black hole information paradox is probably the most important issue for fundamental physics today. If we cannot understand its resolution, then we cannot understand how quantum theory and gravity work together . . . I formulate the paradox as a 'theorem': if quantum gravity effects are confined to within the planck length and the vacuum is unique, then there will be information loss. I conclude with a brief outline of how the paradox is resolved in string theory: quantum gravity effects are not confined to a bounded length (due to an effect termed 'fractionation'), and the information of the hole is spread throughout its interior, creating a 'fuzzball'. (Mathur, 2009b)

The term 'fuzzball' comes from string theory, and its relevance here comes from the fact that string theory is one possible candidate to save the phenomena with respect to the black hole information paradox. The paradox arises from the fact that coupled mix state quantum systems get divided across the event horizon of a black hole, with one quanta going into the hole and another escaping as radiation (Hawking, 2005; Denning and Bell, 2012; Mathur, 2009a; Brustein and Medved, 2015.) There are at least two problems with this. Firstly, the escaped quanta are still in a mixed quantum state according to standard QM, and yet are now not entangled with the quanta in the BH. That's the information loss: loss of half of the physical structure of the coupled quantum system is loss of half of its information. This is not accounted for by the expressions of standard QM. Secondly, the escape of the quanta on the outside of the event horizon should constitute radiation accompanied by perturbations on the surface of the black hole.

The problem is that classical (pre-Hawking) black hole physics does not allow for any irregularities or non-uniformities on the BH surface, and so no radiation could be emerging from it causing nonuniformities in structure (entropy, perturbations.) This is called the 'no hair theorem' because there can be no 'hairy' irregular or nonuniform physical structure on the surface of the BH. The area outside it has to be a perfect vacuum:

> The no hair theorem implied that all information about the collapsing body was lost from the outside region apart from three conserved quantities: the mass, the angular momentum, and the electric charge. This loss of information was not a problem in the classical theory. A classical black hole would last forever and the information could be thought of as preserved inside it but just not very accessible. However, the situation changed when I discovered that quantum effects would cause a black hole to radiate at a steady rate [3]. At least in the approximation I was using the radiation from the black

> hole would be completely thermal and would carry no information [4]. So what would happen to all that information locked inside a black hole that evaporated away and disappeared completely? It seemed the only way the information could come out would be if the radiation was not exactly thermal but had subtle correlations. (Hawking, 2005, 084013-1.)

Note that although this is theoretical physics (a point I will return to in a moment) structure - and particularly the structure associated with physical entropy - is here very much married with information as ineliminable. The concepts are being used interchangeably. Certainly elements of classical statistical measures can be and are applied, but the information itself is regarded on a scientific realist basis as something that can evaporate, that is carried by physical structures, and not just to be transmitted by way of a causal pathway through a medium but to enter and 'come out' of the BH as physical structure. I suggest that this is a vindication of Ladyman and Rosss scientific metaphysics and non-eliminative ontic structural realism, to the extent that I-existing statistics are intrinsic to the physical system as natural content. However, I reassert my conviction that, defeasibly, what are being referred to are stochastic ergodic and nonergodic information sources, and that these are what carry or realise the ineliminable (nonredundant) statistics. Nonredundant statistics reduce to stochastic sources and their dynamics, but sources do not reduce to nonredundant statistics, and at best I-obtaining statistics are a feature of sources. I can allow that they are a necessary but not sufficient condition for the obtaining of a source. Remember that according to Shannon - a source is identical to a stochastic ergodic physical process (a dynamical non-deterministic but parameterised physical system.) Information is essentially *equated* with or taken to be identical to - or at least intrinsic to - the structures of interest. The structures of interest in the passage above are taken to be either excitations of the quantum field, or defeasibly possibly the physical alternative string theoretic substrate (which allows metrics smaller than the Planck length.)

String theory is supposed to offer relief and save the (yet to be experimentally verified) phenomena here because it allows entropy or perturbations to be accounted for on the surface of the BH. According to string theory - the correctness of which is still challenged by many physicists - the information of the black hole is distributed through its volume and across its surface as entropy in the form of transverse wave based perturbations, which are of course a valid candidate to take the label nonuniformities (Mathur, 2009b 42-4.) This is the 'fuzzball'. If the surface of the BH is a fuzzball, then the no-radiation problem is solved. Moreover, with regard to information loss:

> Now there is no information problem: any matter falling onto the fuzzball gets absorbed by the fuzz and is eventually re-radiated with all its information, which is just how any other body would behave. The crucial point is that we do not have a horizon whose vicinity is 'empty space'. The matter making the hole, instead of

> sitting at r = 0, spreads all the way to the horizon. So it can send its information out with the radiation, just like a piece of coal would do (Mathur, 2009b, 44.)

What is important for the purposes of formulating FOSIR based informational metaphysics, however, is that according to both the standard QM picture and the string theoretic hypotheses physical structure is very much information for both quantum physics and high energy BH physics. We know that particles are excitations in the quantum field according to quantum field theory, and so the structure lost is field theory structure: nonuniform heterogeneously comprised quantum field regions constitute the information lost when one quanta disappears into the BH. From the standpoint of a defeasible scientific metaphysics of information, quantum fields are the current best candidate for being exactly what the real structure of OSR actually is at bottom. Defeasibility in the scientific metaphysical character of FOSIR means we can drop the quantum field in favour of strings if we so desire. Developments in black hole physics associated with the information paradox and the so called 'firewall' increasingly make reference to M-Theory (the most mature unified version of string theory) and so provide a potential illustration of how one natural kind - the quantum field and vacuum background - might come to be reduced to or supplanted by (probably the latter - with some overlap) another natural kind - strings and the string field (although the string field is highly speculative and not well understood at this time.) In each case physical structure would be retained, and my argument is that information sources as stochastic dynamical ergodic and non-ergodic structures would - and do - also remain an ineliminable component of the *I* ontology.

There are other ways in which information theoretic terms and concepts are deployed in BH physics [3]:

> In classical gravity, a BH is the definitive prison. Nothing can escape from it. Thus, when matter disappears into a BH, the information encoded is considered as preserved inside it, although inaccessible to outside observers. The situation radically changed when Hawking discovered that quantum effects cause the BH to emit radiation. (Corda, 2015)

Now the discussion centers upon the idea that the information in the interior of the black hole is encoded. This natural *I* encoding is accounted for by the metaphysics I am proposing, and is in keeping with the idea of encoding as energy transduction in Shannon's theory. The energy-transduction based encoding reduces to transmission of influences in the quantum field between excitation regions and these are causally induced configurations of structure.

Consider the following paper abstract which refers to information in the context of physical entropy of the black hole, and to the information being encoded going in and decoded when the black hole gives off (Hawking) radiation:

[3] For another example, see Verlinde, 2011, 24-5.

> We show that, in order to preserve the equivalence principle until late times in unitarily evaporating black holes, the thermodynamic entropy of a black hole must be primarily entropy of entanglement across the event horizon. For such black holes, we show that the information entering a black hole becomes encoded in correlations within a tripartite quantum state, the quantum analogue of a one-time pad, and is only decoded into the outgoing radiation very late in the evaporation. This behavior generically describes the unitary evaporation of highly entangled black holes and requires no specially designed evolution. Our work suggests the existence of a matter-field sum rule for any fundamental theory. Braunstein et al., 2013

This idea of the distribution of information across the inside of a black hole and within other kinds of physical systems in both cosmology and quantum physics often relies upon an apparent association between structural realism and structural complexity (and this in turn is often associated with statistically modeled physical entropy of one kind or another.) Importantly, in both applied mathematics the term 'structure' is often applied to mathematical constructs that are used in modeling physical systems including dynamic stochastic systems. Especially in quantum mechanics - with its competing interpretations - there is a strong tendency to regard the probabilities and statistical distributions on very much a realist basis as existing in the system (this also includes amplitudes and operators.) QM is heavily dependent upon the idea that many of its mathematical elements - operators for example - map directly to physical correlates.

This kind of approach to the nature of information points to something like CICS information and that:

1. It is realist about information as an existing part of the ontology

2. It does not just denote a measure of something (information is not the measure, but that which is measured (Bub, 2005, 543), and statistics underdetermines its nature.)

3. Where there are statistical components (especially for quantum mechanics) in the conception and definition of information (especially quantum information in black hole physics as well as in qubit theory and quantum mechanics), at best the distinction between these and physical existents is not clear, and more often than not both physical phenomena such as entropy and quantum states associated with them are regarded as physical (This is accomodated by Ladyman and Rosss statisticalist ontology - according to which statistics I exists intrinsic to dynamical physical structures.)

As I mentioned above, it is important that black hole physics is theoretical physics. An obvious objection to the science as a support for the CICS and FOSIR metaphysics is that, in accordance with Pauli's doubts about realism about the neutrino, and Einstein's doubts about spooky action at a distance, one should not make scientific metaphysical assertions on the basis of theoretic posits. However, there are some concessions to be made in terms of defeasibility and representation/model-*reliabilism*.

In the context of physics - theoretic physics and applied physics feed into each other epistemically and ontologically in terms of posits and findings. Theoretic physics is often a precursor to discoveries in applied physics [4] and theoretical physics frequently gives rise to posits about dynamics as yet considered out of experimental reach.

I suggest Physicists can make defeasible claims with a much higher confidence in the reliability of their posits due to 1. the manner in which formal physical theoretical knowledge is encoded from natural systems and (I discuss this more fully in chapter 4) 2. the close marriage of mathematics and physics. The manner of encoding is very rigorous and the mathematical encoding rules are repeatable and invariant. This probably has a lot to do with why mathematical constructs in physics - especially QM - deliver such astonishingly accurate and reliable results.

4.4 Armstrong's Eleatic Principle and Information

In *I* FOSIR, just as in Aristotelian mathematical realism, structure is considered not to be ontologically prior so "one can be an Aristotelian *in re* realist, holding that structures exist, but insisting that they are ontologically posterior to the systems that instantiate them" (Shapiro, 1996.) In the context of CICS-FOSIR I've argued that information exists intrinsically to physical structures (nonuniform heterogeneous quantum field regions) only, or those that objectively physically reduce to physical structures (which, according to the physicalism I endorse, includes all real structures) (2003, 75-6.)

The ontic element I identify as that which realises information - the causally induced configuration or arrangement of spatiotemporal causal structure - *underdetermines* the constructed conceptual and theoretic content of all quantitative and semantic theories of information. Yet I have argued that it is immutably part of the ontology of what is modelled by all relevant theories.

The central anti-Platonist assertion supporting the *I* CICS of information is thus that:

1. Platonism about information is wrong because all information is naturally necessarily physically realised by and ontologically reduces to configurations of physical structures. This entails that Platonism about information contradicts physicalism. Platonists about information have selectively neglected

[4]The marked success of Pauli's neutrino posit, Einstein's frame dragging effect (recently reverified using NASA gravity probe) as well as Hensen et al., 2015's recent confirmation of Bell's theorems/posit regarding nonlocal effects, and even more recently the experimental demonstration/detection of gravity waves

the scientific conception of an information source as a physical process with structured states and the scientific conception of data as physically realised.

2. All physically realised information is intrinsically semantic on a causal indicative basis, and there can be no information about a source entity without either information *from* that entity acquired through physical causal pathways or else by way of causally sustained structural covariance (Long, 2014 and see §5 p175.)

The causal indicative nature of all information per 2. is what Julian Barbour has called intrinsic semantic information (Refer to earlier formulations from Stampe, Dretske, and Grice §3.3.1 p114.) Frank Jackson has referred to such indication in terms of the entailment of semantic properties from the structure of physical entities. 2. leads to an informational justification for Armstrong's eleatic principle against Platonism that avoids problems with two primary arguments for the principle: the inductive argument and the epistemic argument from causally sustained knowledge.

The rejection of ON.1 is impossible without committing to strong Platonism - of the kind criticised by Armstrong - about information. It requires abstract entities to be causally interactive with and to be ontologically prior to the physical world for the purposes of information transmission and acquisition. Information objectively exists wherever and only where physical structure exists, and physical structure cannot exist without objectively realising information. Information is essentially physically real according to the *I* CICS *in re* conception because it is realised only and always by the configuration of physical structure. This requirement for the existence of information is very similar in form and consequence to what Armstrong has called the eleatic principle. Anti-Platonist David Armstrong formulated the eleatic principle (EP):

> An entity is to be counted as real if and only if it is capable of participating in causal processes. (Colyvan, 2001)

According to Mark Colyvan, EP has fallen out of favour due to difficulties with its two primary supporting arguments: the inductive and epistemic arguments. The inductive argument proceeds in two stages. First, all of the things which we intuitively take to be "uncontroversially real" are all causally interactive (not a-causal) and spatiotemporally located, and things that are neither are not generally regarded as real(Colyvan, 1998, 121.) Thus real things must all be causally active and spatiotemporally located (Armstrong, 1978 45-7.) This apparently descriptive inductive assertion is then combined with an assumption of naturalism "of almost any variety" to arrive at a normative inductive argument for the causally active status of all real things. The difficulty for this approach arises when we realise that there are some entities - like space time points - which are regarded as real by anti-Platonists and which are not easily assigned either causal efficacy or spatiotemporal location (Malament, 1982, 528.)

For example, mathematical nominalist and anti-Platonist Hartry Field maintains that spacetime points are real, which claim led David Malament to complain that not everything in Field's ontology was trivially non-abstract (Ibid.)

In other words, Field requires spatio-temporally located space-time points to be real for his anti-Platonist ontology, but they do not seem to be causally active, nor even to have spatiotemporal location in any straightforward sense. If spatiotemporal location without causal efficacy is enough for an entity to be regarded as real, then this is contradicts the eleatic principle if spatiotemporally located things are invariably causally active. The problem then becomes one of deciding what the objective criteria are for determination of what is non-controversially real, which destabilises the eleatic principle(Colyvan, 2001, 41-2.)

The epistemic argument for the eliatic principle is that if an entity is not causal, it cannot possibly causally interact with us, or us with it, and so therefore we could never know of its existence. The rebuttal is that there are presumably lots of causal entities (outside our light cone, for example) that we can have no causal interaction with and therefore cannot know by interaction. Thus the epistemic criteria is stripped back to the causal-access inductive argument.

I suggest that physicalist naturalism should require that for space-time points to be real, they must be or have a structure that realises information according to reductionist *I* CICS physicalism about information. I suggest that the criteria for the inductive argument for identifying uncontroversially real entities according to Armstrong's eleatic principle should be that they must somehow be or reduce to concrete information-realising physical structure(s) like spatio-temporal non-uniformities. I am making the same kind of strong reductionist and physicalist proposal as Kolmogorov did of data, and Landauer of the representation thereof: that no real information of any kind exists in the absence of causal (under causal closure PCC) physical structure (according to the quantum field-reducing ontic structural realist metaphysics proposed above.) I have already argued at length for this position, but a basic statement involves existential dependence upon and anti-Platonism about *I* structure: if there was no physical CICS and thus sources, there would be no information at all. To get us to our defeasible FOSIR - no structure, including mathematical representations, cognitive structures, linguistic structures, conceptual structures, or computational structures would exist without the quantum field. Clearly this underdetermines such things as measures of information and semantic encoding of information (lexical and non-lexical), yet it is still both a necessary condition for the obtaining of information, and as I have argued - not trivial physicalism. Thus a spacetime point in a formal model in a theory *can* (but might not) represent a selection or picking out of a feature or location in the *I* structure being modelled.

Thus I suggest:

> Contingent Principle SIE (Structural-Informational eleatic principle): Structures are to be counted as real if and only if they realise (CICS) information.

Spacetime points are generally regarded to be dimensionless and a-causal, and are not realised as any kind of structure or non-uniformity. According to

I CICS realism about information then, space-time points are arguably not real because no information is realised by them. The physical space inside an absolute physical vacuum would contain no concrete structure whatsoever and would also contain no information whatsoever.

The epistemic argument for the eleatic principle is that we could not possibly get any knowledge about entities which are causally inert or idle. If there can be no causal pathway (direct or indirect) from an entity or situation as a distal stimulus to the percipient because the entity is a-causal, then the observer can learn nothing of the distal stimulus. I have made a similar argument about accessibility of information from Platonic entities.

Mark Colyvan asserts that "the eleatic principle motivated by epistemic concerns seems to suffer all the same worries that causal theory of knowledge does." (2001, 42.) Scientists should not stop giving credence to such real entities as unobservable planets existing outside of our light cone just because we cannot have any physical causal (electromagnetic or other radiation-mediated) causal interaction with them (44.) It doesn't follow from there being no causal pathway between an entity and some/any percipient that the entity does not exist (Goldman, 1976, 771.) Colyvan is apparently conflating lack of causal pathway based epistemic access with objective non-existence and exclusion from in-principle causal closure. As a Platonist Colyvan wants platonic entities (which are by definition not causal) to exist without causal access as a confirmation, but Platonic entities are non causal in-principle, whereas particulars subject to the eliatic principle are causal. This appears to stop the attack getting started with a category error.

Armstrong does not mean for causal epistemic access to an entity to be what establishes its objective existence. Armstrong refers to the "causal efficacy" of entities that "act and are acted on… solely in virtue of their nature" and asserts that "things have the causal powers that they have in virtue of their properties" where properties are realised by concrete particulars (1978b, 131-2; 1978a, 46.) In other words, particular entities are capable of participating in causal processes because they are objectively by their nature intrinsically causal and could participate in a physical causal pathway, not because there exists a specific causal pathway between them and a percipient.

Regarding the rebuttal of the inductive argument: for entities outside our light cone I suggest a causal covariance approach which sees universe-wide nomic physical constraints as being realised by the structure of physical sources. The gravity throughout the universe is a physical structure. Such sources thus constrain and determine the information inside and outside of the observer light cone. On this approach a direct causal pathway from a specific out-of-lightcone unobservable source (planets, stars, pulsars etc.) to an observer is not required for acquiring some of its information. Alvin Goldman speaks similarly of "relations between the object and perceiver, plus conditions of the environment" such that a causally acquired "percept is affected by the current state of the environment" (1976, 780-1.) Environmental conditions causally constrain physical structures. Environmental conditions existentially reduce to and depend upon the environment as an encapsulating complex information source, comprised of sub sources.

There exist nomic constraints that are known on the basis of causal evidence - causally acquired information - to be universal. This is based on such things as reference to cosmic background radiation and induction from all observed instances of celestial bodies and radiation. The physical universe (or multiverse, depending on contemporary cosmological theory) in its entirety is a valid causal information source: it is a spatio-temporal complex of causal structured physical structured sub-systems.

Barbour has proposed that the entire physical universe is a configured information source, and Armstrong holds that "the world is nothing but a single spatiotemporal system" which is a good definition of an information source (1976a, 126.) Thus we can inductively make scientifically reliable judgements about the general configuration of the universe source outside of our light cone based on what we know of constants and constraints (including no go constraints) for which we have evidence or causally acquired information from inside our light cone. Examples of such constraints include that the speed of light in all directions must be the same in all inertial frames of reference inside and outside of our light cone, and whatever it is about gravity that makes the inverse squared law apply to measuring it.

It would be physically impossible for these constraints not to apply just outside of the visible universe as they do inside of it, provided the laws of nature hold consistently across the entire information source. This kind of inference is stronger than induction from empirical outcomes, and Ladyman and Ross have noted its prevelance in science:

> [It's] wrong to dismiss the idea that scientific knowledge is sometimes based on the mere generalization of an observed regularity. While it is certainly true that not all science is like this, there are cases that do conform to the simple instrumentalist view of what theories are. For example, it was surely known that Aspirin cures headaches before anyone had any account of the mechanism by which they do so or indeed any account of what Aspirin's molecular structure is. Similarly, much knowledge in science is generated purely by pattern recognition or regression analysis of large amounts of data, and indeed this is increasingly the case. (Ladyman and Ross, 2013, 131)

Thus I propose that FOSIR combined with §4.4 p158 delivers the following hypothesis:

> EI (eleatic Information Principal or no Pseudo-information principle): Information is to be counted as real if and only if it is realised by causally active physical spatiotemporal structures (regions of the quantum field) in accordance with FOSIR.

This is of course defeasible. Correspondingly, the existence of either information generation or transmission is a sufficient condition for the existence of physical structure.

EI and SIE partly answer the problem with the epistemic argument for the eleatic principle by allowing indirect causal pathways, causal pathways from common sources, and physical structural nomically constrained or constraining part-whole encapsulation all to sustain covariance between physical structures thus sustaining information transfer and representation. We can say something about the structure of real planets and suns outside the light cone because of causal co-variance between the inside and outside of the light cone sustained by "laws or processes" as Barbour puts it - that apply to the configuration of both. They both reside within the configuration of a larger information source structure: the nomically constrained universe.

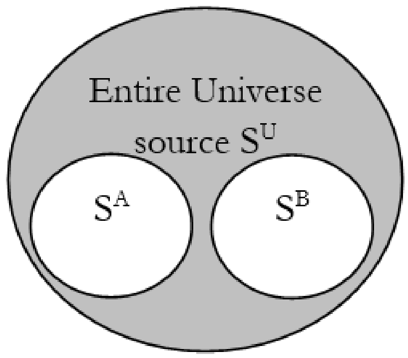

Figure 4.1: Nomic constraints distributed in S^U causally induce the configuration of both S^A and S^B. i.e. There is transmission of common signals from S^U to both S^A and S^B

I don't need a version of the epistemic argument for information, since I have suggested that the sufficient and necessary existential criteria for information is the existence of causally induced configuration of structure that supports signal transmission/emission and encoding by transduction (reducing to transmitted continuous quantum field fluctuations, defeasibly.) That's where the conditions begin and end.

Physicalism is therefore supported by *I* CICS *in re* physical realism (*I* CICS realism) about information because there is ample support from science for the assertion that information can only be realised by, causally acquired from and transmitted through physical structures or structures that reduce to physical structures. SIE coupled with EI delivers the result that only structures that realise information are real. Since only physical structures realise and carry information, only physical structures are real. This fits with out intuition that, objectively, all real things have information associated with them, even if it is only basic information associated with their structure:

1. $\forall x(Ix)$ (Premise: All existing structures realise (and can and do carry) information)

2. $\forall x(Ix \rightarrow Px)$ (Scientifically supported Hypothesis: Hyp): Only physical structures can realise and carry information

3. $\forall x(Px)$(1,2 MP: Only physical structures and structures that reduce to physical structures are real.)

It's important to realise that stipulating that Platonic entities *somehow* track or map to real world representations in - say - mathematical proofs and scientific theories is different to asserting that Platonic entities are information bearing or realise information (and the somehow doesn't matter to strong Platonists, although it might matter to an Aristotelian *in re* realist.) OSIR, IS.1, and IE require something more like physicalist Aristotelian *in re* realism about structure and information. FOSIR delivers a very specific defeasible physicalist characterisation. There does not have to be a causal pathway or causal access to Platonic entities for them to exist in the strong or weak Platonist sense. However, there does have to be such if you want them to realise information, or if you want them to be an information source. A Platonic entity could not be an information source. A spacetime point in a formal theory representation of spacetime is information bearing as a representation, because the representation is a structured source (lexical or diagrammatic, for example.) The information that it encodes as a representation or representing structure(s) is a location picked out of an I physical structure, such that it encodes information from the structure. There necessarily will be a complex of upstream causal transmission channels, reducing to signal pathways, reducing to causal physical pathways (it will be 'messy': neurological sources, linguistic encodings, textual encodings, diagrammatic encodings, instrument channels and so on) that sustain the covariance and what French (following empiricist Van Fraasen) calls a partial isomorphism (for a detailed development of this, see §5.4 p189. For a discussion of physical isomorphism see Szudzik, 2010, 502-5.) Thus another statement of the anti-Platonism of OSIR-FOSIR is flatly eliminative: there is nothing informational for Platonic entities to do between the I structure and the formal representations that encode information from it on a (albeit complicated) causal basis.

4.5 The Question of Infinite Information

The way in which one regards information to exist affects, as far as I can adduce, the answer to the critical question of whether systems contain infinite information. Some key classical statistical and probabilistic conceptions of information in physics are taken to non trivially entail that there is a finite amount of information in the universe. I intuit (for I've not the space to argue it) that this might be retained by some theorists in an attempt to ward off the much debated ontological consequences (inflationary fecundity) of considering that the Everett many worlds interpretation of quantum theory, or some derivative thereof, is true. I do not support the many worlds interpretation, but at the same time my aspiringly contingent ontology of information does not make it a hill I (or my contingent metaphysics) have to die upon.

Some theorists and philosophers have stipulated that there is only a finite amount of information in any given physical system (including the observable universe.) Scientific findings are often cited for this assertion (Davies, 2010, 76-8, 80-1.) Apart from an a-priori stipulation of a finite possibility space (and/or finite source coding alphabet) with classical probabilism about information, it is hard to see how this is justifiable as a broad claim unless perhaps information instead reduces to physical structure, ontic structural realism is true, and Einstein ends up being vindicated in his opinion that the physical universe is discrete at the Planck length, which is in fact a current assumption of quantum mechanics according to many physicists, although the picture for QFT is not so clear.

We are eschewing discussions of a-priorist ontological concepts such as that of gunk. However:

s1. In Shannon's theory the continuous case (continuous or analogue sources) is handled by an approximation to the discrete case. This allows the base 2 logarithmic measure of entropy to be easily applied. Without discretisation, there is no manageable source alphabet or possibility space at the source. Quantification of information per Shannon requires a discretised source probability space and state space

s2. In ontic structural realism, the question of if structure reduces to structure all the way 'down' ontologically (put otherwise - if a recursive constituent-structure-finding function can be applied perpetually.)

However, if structure is the basis of information in the way that I have thus far suggested, and if FOSIR permits structure to be "turtles all the way down" as Simon Saunders' metaphor for recursive reduction of ontic structure has it, then it looks like if there is a potentially infinite structure, it would follow that there is potentially infinite information. I don't think a statistical-realist view like that of Ladyman, Ross, and Kincaid necessarily undoes this. Using the dynamical logic introduced in §1.3.1 p44, my worry is that if it is really contingently structure all the way down, then:

$\left|*^{\iota} S^{U}\right| = \infty$

Where S^U is the universe, and, more potentially at odds with Bekenstein:

$\forall x (Sx \rightarrow (|*^{\iota} x| = \infty))$

(For all x, if x is an information source, then the total information in x is infinite.)

The immediately important observation to make is that the Bekenstein bound requires a system to have not only finite volume or to occupy finite spacetime, but to involve or encapsulate finite energy (Casini, 2008; Bekenstein, 2003.) With this energy constraint removed, presumably included because Jacob Bekenstein integrated a physicalist conception of entropy into his considerations, then we have only structural and volume considerations. In this case structure all the way down probably delivers infinite information despite the Bekenstein bound. In other words, at the level of measures of physical information - which should not themselves be taken to be the information, there is evidently pluralism about the nature of information.

Moreover, with regard to assertions of finite information, I suspect that what has happened in physics is that the classical Shannon inspired probabilistic entropy-orientated model - which requires an approximation of the continuous case by the discrete case for source alphabets and transmission optimisation - has resulted in the assertion of a necessary finitude of information in continuous natural stochastic processes and systems modelled as sources (Shannon, 1998.) This is due, I suspect, such things as the well-regarded Bekenstein bound on the amount of information in finite systems. On the one hand I am vexed by not having the expertise to argue this in terms of the physics to which I wish to defer for authority - certainly not in comparison to the expertise of theorists like Stephen Hawking, Jacob Bekenstein, and Paul Davies (Davies, 2010; Hawking, 2014; Bekenstein, 2003; See also Lee et al., 2013, 1097 which associates this bound with a limit on the number of quantum fields in the universe.) So although I am worried about whether this might stand as a roadblock to my entire FOSIR schema, I am also worried that the turtles all the way down outcome is at the very least an open question, and therefore it doesn't look like it is so straightforward to ward off infinite information in a physical information source.

I will run for the cover of 1. scientific defeasibility in physics and 2. the fact that leading physicists disagree about such things as the many worlds interpretation and the salience and applicability of string theory - both of which seem to affect standard contingent assumptions about how information is realised, how it relates to physical entropy, and what happens in situations like the event horizon and boundaries of black holes (see the discussion about fuzzballs at §4.3.2 p153 below.) For some more detailed treatments including some possible challenges to the finitude of the information in the universe on the basis of what I am referring to as defeasibility that respects the primacy of physics constraints, refer to (I am omitting many worlds interpretations) Bostrom, 2003 245 (including footnote 2); Adami and Steeg, 2014, 13-14; Bekenstein, 2003, 64-5.

Apart from the possibilities presented by continuous quantum field theory models, it's relevant that a current Planck length based discretised maximum information bound of 10^{122} bits of information for the current universe (one proposal due to Lloyd (Ibid.)) defers to a discrete information formula with the possibility space of bits bounded by Planck's constant. Shannon's discrete formula was applied to continuous systems as a mathematical convenience, but this application of the discrete system or model to the continuous case, was, as Shannon himself said, an approximation. In other words, Shannon regarded the measure of information/entropy of continuous sources as a discrete *idealisation.* This involves information loss. Moreover, in quantum terms the decision to equate bits with particles seems arbitrary at best given that QFT says that particles are emergent non-binary features of the quantum field (Floridi, 2009a, 158-9.) Then there is the problem that rejecting digital ontology and Wheeler's it from bit thesis involves rejecting (in most cases) the idea that yes-no questions/answers are the necessary basis for determining information content. If something like qubits are more appropriate at the quantum scale: this does not involve yes-no questions/answers again. Simply stated, qubits as based upon quantum systems are not binary - and for good reason. The non-binariness is due to the strange stochastic nature of quantum systems.

The entire physical universe - considered as infinite - may or may not have a finite amount of information, according to various conceptions and formulations of information. This is apart from defeasibility, and again apart from existing serious proposals (no including many worlds hypotheses) that although the observable universe is finite, the universe is in fact infinite, and may be unbounded in both temporal directions (Hawking, 1993; Wiltshire, 2000; Page, 2007; Kuhfittig and Gladney, 2015.) Then we must consider the information content of the entire physical universe considered as somehow finite across the same criteria. Then we must apply the same question to finite bounded physical systems, including quantum systems. The same question can be applied to the idea of a multiverse considered as finite versus as infinite, but according to my approach the Deutsch-Everett approach is speculative and contravenes POP, and probably causal closure, so I will not attempt to address that. The question of interest here is the information content of a finite physical system according to the CICS-FOSIR conception of information.

Even if Einstein's Planck size discretisation turns out to be contingently confirmed broadly for QFT or whatever alternative theory turns out contingently to be correct, the amount of information in the universe may be infinite. Cantor's transfinite infinities arguably provide a justification for considering that an infinite universe - and certainly a multiverse - which is largely empty of any physical structure, may still have an infinite amount of information: part of an infinity is still an infinity, quantitatively. The same applies to finite, bounded physical subsystems in the universe.

Conceptions of information that render the information content of systems finite are generally expressed in terms of digital ontology and/or pancomputational views, and/or associated algorithmic conceptions:

> It is argued that underlying the Church-Turing hypothesis there is an implicit physical assertion . . . a physical principle: 'every finitely realisable physical system can be perfectly simulated by a universal model computing Turing machine. Classical physics and the universal Turing machine, because the former is continuous and the latter discrete, do not obey the principle, at least in the strong form above'. A class of model computing machines that is the quantum generalisation of the class of Turing machines is described, and it is shown that quantum theory and the 'universal quantum computer' are compatible with the principle . . . the physical version of the Church–Turing principle: 'Every finitely realizable physical system can be perfectly simulated by a universal model computing machine operating by

> finite means.' This formulation is both better defined and more physical than Turing's own way of expressing it. (Deutsch, 1985a, 97-99)

Turing machines are a useful algorithmic fiction with mathematical rule based 'operations' and limits. Deutsch seeks to produce a quantum physically implementable version thereof that is compatible with the constraints of quantum systems because he believes that the physics required for quantum computation entails the *I* existence of multiple worlds. This is the view opposed by Steane, 2003 (see the quotation at §3.4.3 p126 above.) With respect to the question of whether physical systems contain finite information or infinite information - this implies that finite physical systems that can be so represented or simulated have finite information. But this seems to be too quick, even for a metaphysics that regards algorithmic definitions of the nature of information to be compatible with classical statistical and entropy based conceptions.

One way to approach this question of whether a finite physical continuous/analogue information sources (natural dynamical systems and phenomena, for example) necessarily have only finite information is by referring directly to FOSIR. In fact non-eliminative ontic structural realism, and also Floridi's hybridising ISR adaptation - with its information as nonuniformities - will do. According to my view - and also according to Floridi's ISR - information reduces to structure. I have already mentioned the question of reducibility of physical systems and mentioned the views of Ladyman and Ross, Cao, and Simon Saunders regarding the reducibility regress for structure. Even if we specify an arbitrary - or otherwise stipulated stopping point for the existential ontological reduction of structure to other structure, it seems unavoidable that even physical structure in a finite physical system is likely to be infinite. This is even more the case if one thinks that relations are identical to, and/or the ontological ground or necessary condition for structure (and I do not) and that relations are physical. Even if mathematical points are not physical, one can put a mathematical surface or line on a physical surface. It is easy to prove geometrically that there are infinite points on a line segment (Galileo's paradox.) In line with the no abstract wireframe principle I have presented: even if we avoid conflating mathematical and physical structure in the wrong way by inducing mathematical collapse and formalism driven ontological descent, there are infinite possible wireframes that can be picked out of a physical system to represent it. That's just geometric relations, and leaves aside the question of an arbitrary limit to relations that can be identified between features of a physical system based upon their interaction with each other or other properties. Put basically, even if structure in a physical system does not reduce to other structure without terminus, it looks like there must still be infinite relations and infinite structure in an information source. Remember that the assignment of an alphabet for source coding against the states or possible configurations of a source is a discretisation - and thus an abstracting out of or away from the structure - of the source in the continuous case.

Another challenge to the claim of finite information from a discrete and/or digital universe comes from the existence of various continuous physical symmetries in physics (Rickles, 2008c, 180; Martin, 2003, 50-2.) Moreover, how does physics support the idea of finite information in physical systems when some systems are effectively regarded as having infinite dimensions in some sense? This does not require deference to Everettian ontological inflation, but only reference to such things as the infinite proliferation of physical particles (natural kind emergent features of the quantum field) in discussions of black hole radiation (Hawking, 1975, 215-16.)

Some infinities in theories of physics are regarded as aberrative artefacts of the mathematics:

> The Euclidean geometry can be regarded as a black hole moving on a closed loop, as one would expect. However, the corresponding Lorentzian geometry, represents two black holes that come in from infinity in the infinite past, and accelerate away from each other for ever. The moral of this is that one should not take the Lorentzian analytic continuation of a Euclidean geometry literally as a guide to what an observer would see. ... The probability of observing a small black hole, at a given time, is given by the difference between the actions. A similar discussion of correlation functions on the boundary shows that the topologically trivial metrics make black hole formation and evaporation unitary and information preserving. (Hawking, 2005, 72)

Yet, there are different physical parts of the system where infinite physical information - associated with physical dynamical structure(s) - is realised:

> My work with Hartle [9] showed the radiation could be thought of as tunnelling out from inside the black hole ... it could carry information out of the black hole. This explains how a black hole can form and then give out the information about what is inside it ... The information remains firmly in our universe ... If you jump into a black hole, your mass energy will be returned to our universe but in a mangled form which contains the information about what you were like but in a state where it can not be easily recognized. It is like burning an encyclopedia. Information is not lost, if one keeps the smoke and the ashes. But it is difficult to read. (Ibid)

This is an example of what I have called natural encoding. Hawking's deployment of the statistical classical concepts of information do not undermine the fact that there is also a physical conception of information here, and that this is *not* a case of formalism driven ontological descent or mathematical collapse (see also Hawking, 1975, 217-18.)

Shannon's measure is often said to be a measure of the reduction in objective statistical uncertainty about a source state given the state of a signal from that source, and of the next source state given the previous source state. Many theorists have taken this as a definition of information: the reduction in statistical uncertainty. This conception, although popular, has been numerously noted to be problematic, and I will not enumerate the various difficulties here (Cole, 1993, 204-11; Timpson, 2013, 26; Barbour, 2015, 6-8.) There is a related conception of information that defines information and information content as that which is indicated not to exist (Carnap and Bar-Hillel, 1952.) In fact, as physicist Julian Barbour has indicated, the ontic basis of what is measured by Shannon's measure is the structure of - and changes in the structure of – (physical) things (Barbour, 2015, 5-6, 8.) Structured source states are spatiotemporal structures. That is, changes in spatiotemporal structure over time or changes in configuration, which latter can be encoded in many cases by changes in configuration space in phase space representations of dynamical systems (Lyon and Colyvan, 2008.) Thus it reduces to a measure of spatiotemporal structure and changes in physical structures.

It follows from FOSIR and CICS that a complex natural system is in fact a composite information source: a structured complex of finite physical sub-sources (which can be modelled as a set of sources) corresponding to finite physical sub-systems and other constituents whose internal spatiotemporal configurations and overall inter-source arrangement embody information. We can take the ontic boundaries (determined more or less arbitrarily) of a natural system information source to simply correspond to the objective boundaries of the natural system itself as an entity. According to CICS/OSIR information is not descriptions (which are encodings of information), but an ontic simple realised by structure. Natural systems realise information in their spatiotemporal structures. Information is intrinsic to the structure of physical systems, and according to the CICS conception of intrinsic semantic information, all such information can be taken to be semantic in a natural sense (Barbour et al., 2014; Long, 2014.)

It then follows that, with the exception of quantum systems that disobey in-principle the identity of indiscernables, no two physical information sources are informationally identical at some level of reduction (This argument has been applied before to physical events by Hajek in his (Hájek, 1996, 75.)) Information in different sources differs as dramatically as the spatiotemporal configurations of those sources: the structures in which it exists as intrinsic. Information is not a Platonic abstract universal. The total difference in spatiotemporal configuration of a specific zebra and some specific clay is the total difference in the information of each as a natural information source. Concrete specific instances of water, zebras, molecules, flocks of birds, iron ore, gamma rays and stars are all instances of information sources. Such entities all naturally necessarily realise some specific information as instrinsic to their individual and unique specific spatiotemporal structures: their configurations. Although at the quantum level symmetry dictates that the evolution of a system is predictable in some cases within certain limits, at both quantum and macro-level there are strong reasons associated with algorithmic complexity and information depth (in terms of the computability of physical structures Deutsch, 1985a, 114) and nonlinear dynamics to doubt that an entity or spatiotemporal structure could be perfectly duplicated based upon entropy in natural systems and the laws of thermodynamics.

4.6 Conclusion

In this chapter I attempted to argue, largely via inference to the best explanation combined with my indispensability of information argument, for a contingent and defeasible basis for OSIR in QFT. More specifically, that basis is the quantum field and vacuum background. I also further developed the argument from the previous chapter that the assertion that relations are structures and therefore relations are the basis of the I ontology is a mistake. The overriding consideration is that the tendency to see relations as primary or as the ontic ground of structure - or as the necessary condition for structure - comes formalism driven ontological descent, or else from French's mathematical collapse.

Acquisition of data from natural systems in scientific research involves the physical extraction of information that is or reduces to physical configurations of physical structures: the *physical* information in/of the physical structures of the material world. There may be relations involved in encoding the information into representations, and there may be relations in the objective spatiotemporal causal structures themselves, but the structures are continuous in temporal and spatial dimensions as far as science can determine. Any entities identified for the purposes of modelling and representation are also heterogeneous structures. According to the naturalistic physicalist I conception, these structures all reduce to physical causal spatiotemporal structures. A general statement of the idea is that no representation of an I-obtaining natural structure can exist without the causally induced configuration of other natural structure(s), amounting to the encoding of information from the former in the latter.

I went on to provide a defeasible, contingent, reductionist characterisation of the ontology that is the subject of scientific study, providing a metaphysical basis for the idea that the world, rather than being the totality of nonredundant statistics, is instead the totality of stochastic ergodic and nonergodic information sources. I argued that although such information sources (dynamical natural systems with dynamical structures) are intrinsically statistical by dint of being stochastic: it is the stochasticity that existentially depends upon and is a necessary, *but underdetermining* condition for, the existence of information sources thus defined.

In the previous chapter I presented a new informational statement of physicalism, which is intended to strengthen the best existing conception of physicalism. In this chapter I revised David Armstrong's a-priori analytic (in fact Armstrong's metaphysics is significantly contingent) eliatic principle, developing an information theoretic version which defeasibly defers to FOSIR. This is by way of an argument that there is no information without the right kind of physical spatiotemporal structure, and that in fact all information must reduce to very specific feature of such structure(s) (their configurations or arrangements.)

Quantitative communication and transmission theories generally deal with physical information generation, encoding, transmission, decoding, reception, and processing. Quantitative algorithmic theories of information generally present measures of information in terms of numbers of structural units or the length of formal descriptions and/or atomic string objects. According to FOSIR, causally induced configurations of spatiotemporal causal structure (CICS) is both a necessary and sufficient condition for the existence of information. In this chapter I moved from a general statement of this to a specific, defeasible, contingent scientific-metaphysical statement of it, which I can now summarise thus:

> IS1 (Informational Structuralism 1): Information is (reduces to and is identical to) the causally induced configuration/arrangement of any I-obtaining physical structure, the configuration or arrangement of which has been caused or causally induced (via causal pathways) by some other causal spatiotemporal I structure(s), or to structure(s) that reduce to such structure(s) (CICS information hereafter.)
>
> IS2 (Informational Structuralism 2): I structure(s) reduce(s), on a defeasible basis, to nonuniform heterogeneous regions of the I-obtaining quantum field.

IS1 is essentially a statement of OSIR. IS2 is a statement of FOSIR, and embodies the identity between I-obtaining physical structure and nonuniform regions of the heterogeneous quantum field, defeasibly.

This is the limit of my development of FOSIR as a source-centric (I-obtaining stochastic CICS system centric) scientific metaphysics of information, until further work in the last chapters. In the next chapter I will outline a causal indicative conception of the semantic content of information as I have characterised it thus far, and in so doing I lay a foundation for (but not complete) a solution to the symbol grounding problem.

Part III

Intrinsically Semantic Information, and Further FOSIR-CICS Source Ontology Development

Chapter 5

Information is Intrinsically Semantic, but Alethically Neutral

5.1 Introduction

In this chapter I argue that, according to the CICS-(F)OSIR conception of information, information is both alethically neutral or non-alethic, and is intrinsically semantic. It's intrinsically semantic on a reductionist and non-alethic basis where semantic content is constituted by indication along causal pathways, often in conjunction with transduction and encoding. Similar arguments have been presented by philosophers with respect to representation (see §3.3.1 p111 and §4.4 p158.) The upshot of using OSIR as a scientific metaphysics of information with indicative semantic content is that there is no need for any separate theory of semantic information (a claim familiar from Adriaans' different view that semantic content is already accounted for in classical information theory and complexity theory Adriaans, 2010.) Thus in chapters one through four I've presented the ontological basis for a theory of *intrinsically* semantic information. I will argue it also constitutes an informational theory of truth where truth reduces to information. In the last section I discuss weakly and strongly semantic information, and reject them in favour of alethically neutral intrinsically semantic information.

The possibility of the naturalisation of information is the central metaphysical issue in this thesis (Floridi, 2011c, 42-3.) Closely allied with the debate about whether the metaphysics of information should be naturalised at all, and if so, how, is the question of whether the metaphysics of any theory of semantic information should be naturalised. I think that information as I have characterised (CICS) it is intrinisically semantic on a causal and indicative basis, and that therefore no additional separate semantic theory of information is necessary. The former is naturalised and thus so is the latter. This view is not common.

Philosophers and mathematicians have offered several theories of semantic information, mostly based upon a variety of mathematical constructs. The first serious attempt at a semantic theory of information is arguably that of Rudolph Carnap and mathematician Yehoshua Bar-Hillel (Carnap and Bar-Hillel, 1952 [1]), according to which Shannon's statisticalist conception of information constitutes a description of the metaphysics of information (although it is less clear what this actually means that might be expected). Carnap and Bar Hillel produced a theory of the semantic information based upon a definition of the information content of sentences that are state descriptions (descriptions of the state of a Shannon source). The content reduces to a possibility space of state descriptions: specifically those that do not obtain at the source. This approach was adapted from Carnap's logical probabilities (Carnap, 1945; Carnap, 1950) and the principle of a space of possible information source states (source alphabet) as presented in Claude Shannon's *Mathematical Theory of Communication.* (Dretske, 1981) also adapted elements of Shannon's theory to produce a theory of semantic information in which semantic content reduces to the intentional content of the information in a physical signal produced/caused by a physical Shannon source construed in a certain technical statistical manner.

According to Floridi's informational structural realism, which he labels ISR, and his strongly semantic theory of information (§5.7 p200), data representation, and data as representing structures, can be non-physical concrete or abstract differences *de re.* OSIR-CICS does not allow either. According to (F)OSIR, CICS - and therefore information - necessarily reduces to structural physical nonuniformities that are non-binary and *in re* (refer to §6.2 p208, 44.) The (F)OSIR conception of information is dataless, and according to OSIR data is a structured representation of a selection of information from an I obtaining source system.

Floridi has argued that such a physicalist *in re* conception of information as that which I present here cannot explain the nature and semantic character of information, and he has produced a theory of strongly semantic information that is linked via his conception of data and cohering clusters of data, via a correctness theory of truth, to his ISR. I oppose Floridi's position by starting with the following premise/hypothesis:

> P1) CICS information is intrinsically semantic on a causal basis, and no separate special theory of semantic information is necessary.

Dretske's theory includes a conception of intentional information content of a (physical) signal that is not dependent upon mind and language based representations like sentences, messages or statements (Dretske, 1981, 75-7.) Floridi has referred to this kind of conception under the head of naturalising information and as an externalist naturalistic conception of information: externalism about information (Floridi, 2004a, 54; Floridi, 2010b, 42.)

[1]See also Bar-Hillel and Carnap, 1953;

I'll argue that *I* CICS information is intrinsically semantic in a number of different ways on the basis of causally sustained indication similar to that which is the basis of Dretske's informational signal intentionality. It indicates something about the existence and, to varying degrees, about the configuration of the upstream source(s) and causal pathways (also sources) that causally induced it (Dretske, 1988a, 58; Dretske, 1981, 42-4.) However, my claim is that this does not make CICS sources and information alethic, but only makes them truthmakers:

> P2) Intrinsically semantic (*I* CICS) information is not alethic: it has no alethic value.

Information's semantic content comes from the indication of causally upstream CICS-reducing sources. Floridi's strongly semantic information "is not a *truth-bearer* but already encapsulates truth as truthfulness" (Floridi, 2010c; Floridi, 2011c, 106.) Dretske asserts that there is no such thing as false information and what is normally referred to as "false information and misinformation are not kinds of information - any more than decoy ducks and rubber ducks are real ducks"(Dretske, 1981, 45; Floridi, 2010a, 92.) Floridi's view and that of Dretske is that information has an alethic value because it is only ever true and cannot be false (Floridi, 2005a, 25, 30.) However, I will argue that this is a misconstrual of the relationship between information and truth, and that this is demonstrated by the fact that according to the aforementioned assertion information is always true, which outcome seems to be alethically redundant. I suggest that what should have been claimed is that only information bearing structures are real. My view is that information is not true in any truth-functional or alethic sense. My argument is that information is not truth apt and neither is it a truth-bearer. Nor does it encapsulate or embody truth. To ascribe alethic value to information is to commit a category mistake.

Put otherwise, when compared to a correspondence theory of truth, this theory says that it is not an item picked out in the world that is the truthmaker for encoded information (including descriptions and statements.) Instead, the CICS information of the sources contributing to the configuring signal plus the signal as a CICS source constitute the truthmakers. According to most familiar terms and concepts in philosophy P2 can be taken to be either just confused, or else a contradiction, or both. However, the (F)OSIR-CICS conception of information and P1 provides a way of avoiding any contradiction. I take this to be hinted at by the intuition shared by Floridi and Dretske that there is no such thing as false information.

Thus I will propose that *I* CICS information - reducing as it does to features of structures existing according to physicalist non-eliminative ontic structural realism - is a special kind of truthmaker. Truth reduces to *I*-CICS information, and not vice versa. A consequence is that I endorse what Floridi has called an informational truth theory: a theory according to which "an informational approach can explain truth" (2010; 2011, 34.) Information is a non-alethic truthmaker.

To help establish P1 and P2 I will analyse certain concepts in both the weakly and strongly semantic theories of information. Initially, however, I will introduce some background to semantic theories of information - specifically those of Devlin, Dretske, and Carnap and Bar-Hillel.

5.2 Logical Probabilities and Situation Theory

5.2.1 Devlin's Abstract Infon

Situation theoretic semantic information theory carves the world up into states of affairs or situations (Devlin, 1991, 20-7.) A situation is exactly what it sounds like: a scenario or state of affairs involving different objects and interactions between them. The situation is a part of the informational logic – the logic based upon information – the development of which Devlin attempts as his primary endeavour. Unusually, the nature and ontology of information was a somewhat secondary and supporting concern in making information the basis of Devlin's new logic (Devlin, 1991, 4, 6, 10.) According to Devlin's theory, concrete situations encapsulate and embody information: they are informational. The situation where a reader is reading this sentence is one which is full of information.

Devlin's semantic theory of information models the situation using a collection of abstract representational atoms or elements called infons. Infons are an abstract semantic or meaningful constructs that represent parts of the situation (Ibid., 45-6, 46-7.) Floridi adopts the infon in his own later theory of strongly semantic information, marrying it to his conception of data. Infons are semantic both because they can correspond to elements of the concrete material situation, and because they can be true or false depending on whether or not the situation actually exists as described by the infon. As such, abstract situations and abstract infons are part of the theory, and an infon can exist without mapping to any real situation and yet is still regarded as informational or information-bearing (Ibid., 11.)

An infon is an abstractum with no "form of physical existence". Its syntactic representation describes a set of individuals (objects), a predicate expressing a relation between those individuals, a truth or falsity indicator that states whether the relation holds between the objects, and parameters indicating a time and location of the relation between the objects. An infon is made true by a situation, but does not have to correspond to a *concrete* situation. Devlin defines Infons as "semantic objects, not syntactic representations." (23.) Infons as semantic physical symbol based representations have meaning in terms of corresponding to real world states of affairs and entities: real or concrete situations.

The real situation where I am typing this sentence in Glenbrook at 11:00 p.m. makes true the item of information or infon expressed as:

$$\sigma = << Typing, Bruce, ThePreviousSentence, Glenbrook, 11:00p.m., 1 >>$$

The relation or predicate is Typing, since Bruce (an object) was typing the sentence (an object.) The objects in the situation captured by this particular infon that are the things related by the relation (the relata): Bruce and the previous sentence. The location and time parameters are Glenbrook and 11:00 p.m. respectively, and the 1 is a polarity which can have the value 0 or 1 corresponding to true or false to indicate that the situation is either real or not real respectively. This approach to information is quite different to Shannon's, except that the situation, like the process that produces information in Shannon's theory, is regarded as the origin or source of the information:

> [D]ifferent [cognitive] agents are capable of extracting different information from the same source (situation.) (Devlin, 1991, 14)

Infons, then, describe or represent information sources. Consider the infon:

$$\sigma = << Splashing, SpecificToddler, Bathwater, Bathroom, Bathtime, 1 >>`$$

This expression representing a semantic infon would be made true by the situation (source) where an actual specific toddler is splashing water in a real physical bathroom at bath time. The splashing toddler situation is a dynamic causal process: a source of information. A situation is where the information first exists and comes from. To write down an infon that is true, however, it might seem that one need not have received information from the situation as a source: the specific concrete situation simply has to be objectively real. An infon – a semantic abstract entity or construct that represents - is made true if the situation which it represents a part of is real. However, the infon is still somehow comprised of information if the situation does not objectively obtain (such that the polarity parameter would be 0 not 1.) Herein lies the problem.

There is clearly no way of establishing the truth of a situation in terms of information for representation without information causally acquired from the situation as a concrete causal structure via signal transmission (and some complex encoding procedures using many ontologically differently implemented effective source code alphabets.) One simply cannot encode into a physical representing structure (involving physical symbols) the information that the toddler really is or was splashing in the bath without some causal pathway from the splashing-toddler situation to the encoding symbols/structure. A true description based on objective correspondence is perhaps tenable without such a causal linkage or flow of information, but an encoded informational representation is naturally/physically necessarily not possible.

Infons are the semantic mathematical abstracta used in Devlin's theory to represent parts of concrete and abstract situations. Although information is said to originate in and be part of concrete situations, and infons are abstract semantic structured representations of parts of such situations, infons as abstract constructs themselves become informational and information bearing - what information itself is somehow comprised of on Devlin's theory. Although Devlin is a professed naturalistic realist about information who assumes "that there is such a thing in the world as information", this abstract infon-centric approach makes a coherent definition and conception of information elusive. This 'infonic' approach invites formalism driven ontological descent, because the infon, which, in Devlin's and Floridi's characterisations, can be abstract (in a Platonic sense) due to its designation as an atom of information taken to be an abstract commodity per Dretske's liberal naturalised conception of information. The descent occurs when the (Platonic) abstract infon, *the representation of which* can be deployed as an apt representation of a concrete situation of some kind, is taken in and of itself to be informational. Such an abstractum is not informational, as it has no real transmission-apt structure. Especially according to the terms of my characterisation or information as the causally induced configuration of a structure which necessarily reduces to structures inhering intrinsically *in re* in the quantum field (CICS+QFT), a representation of such and infon is a itself pseudo-representation that picks out a pseudo-source (pseudo-situation.) The abstract infon itself if a fiction, and not a real information source: it is not part of the ontology of the world because it is not an information source. To assert that it is informational - carries information content in its representing structure - is an error. This is more than just the idea that the pseudo-representation of the abstract infon deployed as a pseudo-representation of some upstream sources is false as a truth bearer from a correspondence theoretic perspective. It's the assertion that there is no such thing as a real abstract infon information source: it's a virtual source. I introduced the concept of virtual sources at §2.3.1 p68 and develop it further below at §5.6 p199.

5.2.2 Carnap and Bar Hillel : Abstract Information Content

Bar-Hillel and Carnap's theory of semantic information requires that semantic information content is realised in abstract spaces by abstract entities: by the abstract negations of abstract state descriptions or propositions. Information is realised as a set or class of 'something':

> We have committed ourselves to treat information as a set or class of something. That set of something is E - the set of information content elements of a sentence or state description. (Carnap and Bar-Hillel, 1952).

Carnap and Bar-Hillel were attempting to address the semantic shortcomings of theories developed from Shannon's quantitative theory, which specifies no semantic aspect of information. They define a formal language L_n^π such that there are n individuals $a_1, a_2, \ldots, a_n$ and π primitive properties $P_1, P_2, \ldots, P_\pi$ that can apply to the individual. There are thus πn possible atomic statements (also called atomic sentences or basic sentences) which look like the example $P_1 a_1$ (object a_1 has property P_1.) A disjunction of such atomic statements (a molecular sentence) is called a content element:

> A disjunction which, for each of the πn atomic statements, con-

tains either this statement or its negation (but not both) as a component, will be called a content-element.

The class of all such content-elements (molecular sentences) that are L-implied (logically implied) by a given atomic statement i (or $P_i a_i$) constitute the information content of the atomic statement . This is denoted $Cont(i)$:

A content-element is defined as the negation of a state-description, and the content of $i - Cont(i)$ - as the class of the content-elements L-implied by i.

$Cont(i)$ applies to factual state sentences and propositions – those based upon empirical observation the truth of which is determined by material facts - and to analytic sentences the truth of which is established purely logically. Since a state description will be a conjunction of some atomic sentences (or else what Bar-Hillel and Carnap call Q-sentences), the negation of a state description will be a disjunction comprised of the negation of each atomic sentence in the (molecular) state description. For example, if there is a system with three individuals or objects ($n = 3$) a, b and c defined to be humans, and two properties ($\pi = 2$) M designating male (with M or F for female) and Y (with Y or O being old), then given state description:

1. $Ma \wedge Ya \wedge Fb \wedge Yb \wedge Fc \wedge Yc$($th$ is is i),
its negation will be
2. $(Ma \wedge Ya \wedge Fb \wedge Yb \wedge Fc \wedge Yc)$($th$ that is, i)
which is logically equivalent to
3. $Fa \vee Oa \vee Mb \vee Ob \vee Mc \vee Oc$

Hence 2. and 3. are both referred to as content elements by Bar-Hillel and Carnap (see the previous two quotes.) Now, V_Z is the class of all πn molecular state descriptions i that can be formulated from a certain set of n individuals and a certain set of π properties. $R(i)$ is all of the state descriptions in the class of πn state descriptions that L-imply i. $R(i)$ is called the range of the state description i.

Alternatively formulated, i says that the universe is not in one of those states which are described by the Z in $V_Z - R(i)$, where V_Z is the class of all Z. Just as i is L-implied by every Z in $R(i)$, so it L-implies the negation of every Z in $V_Z - R(i)$. We call these negations the content-elements E of i and their class the content of i, in symbols $Cont(i)$.

In our example, one of these would be 1. above which L-implies $Ma \wedge Ya \wedge Fb \wedge Yb$. Thus 2. is a negation of a state description in the range of $Ma \wedge Ya \wedge Fb \wedge Yb$ and is one of the abstract state descriptions in that set that realises the information of $Ma \wedge Ya \wedge Fb \wedge Yb$ (and of any natural language sentence that expresses this.) The theory is developed at length in *An Outline of a Semantic Theory of Information*, which details many theorems and axioms. What is important here, however, is that the information content $Cont(i)$ of a state description or sentence i is realised by the negations all of the abstract state descriptions which describe how the world is not if I states how the world actually is. Thus information content is most certainly realised in abstract terms by abstract entities. Even if Carnap is not a Platonist about such entities, and this position is perhaps tenuous at best (W.V.O Quine argued that he could not avoid the charge because the Quine-Putnam indispensability argument for the existence of platonic mathematical entities commits the *mathematical* realist Carnap to Platonism Alspector-Kelly, 2001, 93-94, 99-100; Quine, 1951; Quine, 1960, 275), then we still have information realised in an abstract space where there is no physical structure and no kind of source.

Carnap and Bar-Hillel offer $Cont(i)$ as "an explicatum for the ordinary concept 'the information conveyed by the statement i', taken in its semantic sense." It is said to be so because, at minimum, if atomic statement i L-implies atomic statement j then $Cont(i)$ includes $Cont(j)$. If Carnap's denial of Platonism holds, then the conception of abstract information here might be taken to be information as abstracted from facts and expressed in factual state descriptions. This would involve something more like Aristotelian *in re* physical realism about information. In Carnap and Bar-Hillel's semantic theory the information content of an asserted factual sentence with observational or empirical terms is realised when the sentence is asserted about an obtaining state of affairs. Analytic sentences or state descriptions including mathematical statements are taken to have null information content. The information content of '2+2=4' is null. A true factual sentence is required for non-null information content. It thus very much seems that this confirms the intuition that semantic information can only exist in real physical facts: real physical states of affairs or structures. That there is no such thing as false information or information existing apart from real facts and data – without concrete (but not necessarily physical) information sources and data - is certainly asserted by philosophers like Dretske and Floridi. This doesn't negate the fact, however, that in its existing form, Cont(i) ascribes the realisation of information to negations of abstract state descriptions in the range of a given state description: an abstract set of abstract descriptions of all the ways the world is not for specific individuals and predicates.

Bar-Hillel and Carnap also develop measures of amounts of semantic information based on E. This seems very much to assume that (semantic) information exists in such a way as to be mass-quantifiable. It seems unintuitive at least to describe something assumed not to be real (all of the state of the world that do not obtain) in any world using a mass term, without the mass term being any more than metaphorical, or else fictional-nominalist. I should not impose my own style of materialist realism upon such measures, and yet it remains the case that if the mass term is nominalist-fictionalist in nature, then according to Carnap and Bar-Hillel's theory the fiction is about something that does not exist. Thus it seems that a fictionalist mass term is arguably also inappropriate and invites the attribution of category error. To say one can apply a measure to the number of utility belts that Batman does own seems plausible, but to apply a measure to the number of utility belts he does not own seems implausible. I cannot offer a better analysis here than to say I think it is arguably inconceivable in the manner that round squares are inconceivable. That said, I do not think that conceivability entails possibility in any case (contra David Chalmers and many other serious opponents Chalmers and Balog, 2009).

Bar-Hillel and Carnap offer two different implementations of a measure of the amount of information in a state description: $cont(i)$ (note the small 'c') and $inf(i)$. The former delivers numeric values based upon logical probability spaces, the latter is a similarly derived analogue to Shannon's quantitative information measure . The measure of semantic information in an analytically true mathematical sentence is 0. On the other hand, the $Cont(i)$ (content, large 'C') of an L-False mathematical statement is maximum since a logically false state description L-implies all possible state descriptions. However, even Platonists about information like Floridi and Dretske agree that there is no such thing as false information. False information and misinformation: these are "not kinds of information - any more than decoy ducks and rubber ducks are kinds of ducks" .

Natural information like that intrinsic to DNA, RNA and proteins is never true or false: it is always just information. It can be affected by noise sources (yet other causal structures) which may result in less complete or lower fidelity imprints of the configuration of the sources which caused it. Noise, however, does not make information false – just noisy.

Approaches like that of Devlin and Bar-Hillel and Carnap, and that of Chalmers and Jackson, 2001 (345), rely on real abstract descriptions or representations of various kinds. Such descriptions are inherently abstract. This results in situations where the abstract descriptions that realise information content are taken to exist before that which is described. This has the undesirable result that the information of a physical structure or situation is not only abstract and exists apart from any concrete state of affairs, but exists as a description of the concrete structure prior to the existence of the structure itself. Descriptions are about concrete structures, sources or situations. When information is equated with abstract descriptions the information is taken to exist apart from and before that which is described .

The problem with description based or description-centric theories of semantic information is revealed in the use of the preposition 'about' with reference to information associated with some entity or situation. Consider the sentences "I want information about troop movements" or "This is the information about that test subject". What these statements respectively can be seen to mean in terms of the structured situations in question is "I want a description in natural (or formal, or mathematical, or scientific) language that captures and encodes information from the troop movement situation" and "I want a description/theory in natural (or formal, or mathematical, or scientific) language that encodes information from the test subject entity and/or the situation of the experiment on the test subject". In order to have information about specific troop movements or about specific test subjects in the prepositional sense, it is naturally necessary that information must be acquired from the situations and entities in question. This acquisition may be very indirect, and may involve the combination or synthesis of the information with that from other sources. Nevertheless, information must come from the sources in question and its acquisition must be effected through causal pathways.

There seem to be two senses of information implicated here, one which is ontological and pertains to the arrangement and structure of facts and objects in the situations of interest, and one which is epistemic and based on descriptions thereof. Observe that the descriptions in the above scenarios can only be developed by encoding information that has been causally acquired from the concrete structure of existing situations and entities. Acquisition of information existing in troop movements or a test subject is achieved by causal observation and measurement in concrete situation or entities via channels that necessarily must reduce to physical signal pathways and thus causal pathways (Ladyman et al., 2007, 208, 210, 212-14.) Descriptions and theories are encoded to re-represent the information in the CICS information of their own physical structures. Structural and non-descriptive information exists in the concrete situations and entities before the causal acquisition and encoding of information produces any descriptions using certain rule-based codes involving symbols and natural language lexicons. Information is not (identical to) descriptions. Descriptions causally encode information causally acquired from physical structures and situations. Descriptions (and other kinds of representations) are not prior to the information they encode, unless they have been encoded from a very similarly structured situation and are thus apt encoders.

Information can not exist ontically prior to the structured distal source in and from which it originated. Such structured distal information sources must be physical and causal, otherwise no information can be acquired or transmitted from them. A representing structure that was encoded (including constructively) on the basis of similar sources in the past may be an *apt* structure to use to encode representations of the new source, but such a prior apt representing structure is not the information in the new source itself: it is only apt to represent it.

Correspondingly, given two concrete structured situations or sources S^A and S^B which have the same structural configurations, the information in S^A is not in fact the same as the information in S^B:

$$(S^A \cong S^B) \nrightarrow (*_i^\alpha S^A \equiv *_i^\alpha S^B)$$

Read as "that the structure of source A is isomorphic to the structure of source B does not imply that the information of source A is identical to the information of source B". In fact, the stronger modal result applies:

$$\neg \Diamond \, [(S^A \neq S^B) {}^\wedge (S^A \cong S^B) \wedge (*_i^\alpha S^A \equiv *_i^\alpha S^B)]$$

Read as "it is not possible that if S^A and S^B are not identical (the same source), and S^A and S^B are physically isomorphic, that the information of S^A is the same as that of S^B"

Dretske argues that if information sources S^A and S^B generate identical messages, the (semantic) information generated by (information source) S^A is not the same as the information generated by S^B precisely because it was not generated by S^B, but by S^A. The intentionality of the generated information – which becomes the informational content of a signal in Dretske's theory – is determined by the specific individual source which generated it. The information generated by S^B is of and from S^B, it is not of and not from S^A.

Descriptions referred to as 'information about' S^A are naturally/physically necessarily based on encoded information causally acquired from the structure of S^A. Roughly, if you and I both tell Sally "My pet rabbit died", we are giving Sally the same message (the signal might even be a duplicate) but not giving her the same information. This applies even if your rabbit and my rabbit (two physically separate rabbits) are identical physically in every respect, and died in exactly the same way in the same place. It is relative to the structure of each of our respective dead rabbit situations as sources. Thus Dretske rejects that information is some kind of universal, and I agree.

If we both tell Sally that *her* one and only pet rabbit (a third distinct rabbit source) died in exactly the same words, then we are each giving Sally a duplicate of the same message, and we are also giving her the same (core) information. However, this is because in the case where it is Sally's rabbit that has died the original source of information for both encoded messages (descriptions) is the same causally upstream dead rabbit situation. (see §5.4.1 p190 below for more about accidentally and incidentally co-varying structures/sources.)

5.3 Dretske's Information Semantics

Scientific theories, explanations and descriptions all use information to encode representations of the information at/of natural sources. Scientific representations are developed using instrument (and observation) captured emissions as signals through causal pathways from such system-sources: i.e. via physical information channels (See also Ladyman et al., 2007, 208, 212.) Due to the dynamics of necessary partial representation in effect complexes and causal pathways, there will necessarily be only a partial isomorphism between the structures of any scientific representation - which structures supervene upon the information at the entities (sources) supporting the representation - and the spatiotemporal configuration of the represented system-source. The physical and causal dynamics and constraints underlying information loss (see section 1.v and (ii) above) enforce what pragmatic pluralists refer to as the necessary partial character of all scientific representations including all models and descriptions (Mitchell, 2009, 23, 31, 33.; Wimsatt, 2006, 684.) Scientific explanations require descriptions (Among other things: models, diagrammatic representations, mathematical algorithms etc.) Descriptions are produced by semantic sentential encoding of the results of analyses of effect complexes from natural systems (raw data) acquired through necessarily casual instrument and observation interactions.

According to Dretske physical signals used to transmit encoded physical symbols produced by a source (caused by the consecutive successive physical states of a source and transitions from one state to the next considered discretely) have intentional information content. Dretske argues that the intentional information content of an individual signal depends upon the satisfaction of three requirements, two of which are expressley quantitative:

1. The signal carries as much information about s as would be generated by s's being F (where s denotes a source and F denotes the current state and structure of the source)

2. s is (in fact) F (In other words, the state of the source s is I F)

3. The quantity of information the signal carries about s is (or includes) the quantity of information generated by s's being F (and not, say, by s's being G)

Dretske's probabilistic conception of information in a signal depends upon a statistical *measure* of the *quantity* of information (which measure is also referred to, somewhat confusingly, as the information.) The problem with 3. above is that the *quantity* of information encoded into the signal tells one nothing about which state obtained at the source:

> It is not clear what it could mean to say that one quantity (amount of information the signal carries) is (or includes) another quantity (amount of information generated) *when this is meant to imply something more than numerical comparison.* (Dretske, 1988a, 64.)

Aboutness has been lost as the probabilistic Shannonian conception only makes measured quantities available. More importantly, the measure is one of an amount of something, but the measure cannot sensibly be taken to be that which it measures.

In trying to identify the semantic content of Shannon information, Dretske goes on to isolate a single signal rather than an average of signals and messages (sequences of symbols constituted by sequences of physical signals produced in a medium by an encoder) over time as important (18.) He then defines the information content of a particular individual signal as the likelihood that a certain state obtains at the source based upon i) the message received at the receiver and ii) a factor k which constitutes the receiver's previously acquired knowledge of the possibilities that can obtain at the source (Dretske, 1988a, 65, 80-82.)

The introduction of this k factor places stress upon the externalist nature of the conception of information that Dretske starts with: the conception of the nature of information is no longer I with this apparently epistemic 'k'-factor characterisation deployed (See Taylor, 1987, 100.) However, Dretske then offers a simpler statement of the information content of a signal that is intentional by way of being what I will call (using the terminology Dretske uses in his 19) *indicative*:

> The information content of a signal is being expressed in the form "s is F" where the letter s is understood to be an *indexical* or *demonstrative* element referring to some item at the source. What the definition gives us is what philosophers might call the signal's *de re* information content. (66)

This is in line with 2. (See above.) Dretske here introduces the concept of (intentional) reference in relation to the signal caused by a source. F is a specification of the nature, structure, and properties of s. I regard this latter *non-probabilistic* aspect of Dretske's conception of the information content of a signal - with some adjustments involving the elimination of statistical constructs and elements - as the right conception with which to proceed. However, there are some distinctions to make and some more conceptual work to be done with the ontology.

I suggest that where information is concerned correspondence, intentionality (or intentional reference), and indication are all importantly different. In bringing to bear the ontology of physicalist structural realism upon indication, my conception of indication differs only slightly from Godfrey-Smith's: "Indication is a relation between types of states of affairs; indication relates facts, not things." (Godfrey-Smith, 1992, 285.) I agree that the indication is between states of affairs, in so far as these are sources and are CICS structures. However, because physicalist structural realism provides the ontology of CICS information, things are retained in the ontology as themselves structured sources or states of affairs. With physicalist structural realism the relation in question has to be constituted of physical causal pathway(s) - the indication relation is causally sustained.

Put otherwise, usually intentionality is about one structure picking out another structure in the world somehow on some basis (a relation of some kind is implied) - with the means of the picking out being abstracted out. The intentional content is just picked out or pointed to *somehow*. Godfrey-Smith points out that Dretske seems to equate the somehow with the actual causal pathway(s) for the intentional content of a *representation* (Godfrey-Smith, 1992, 285-6.)

Thus I am not the first to argue that indication and/or causation are the basis of a naturalistic information-theoretic conception of semantic content (Dretske, 1988b; Dretske, 1995; Godfrey-Smith, 1992; See Stampe, 1986 for an application specifically to *representations*. Kripke's causal reference chains are an important example.) However, I am not aware of any approach according to which the indication is the necessary and sufficient condition for *information* of any kind to be semantic, and this is characterised by all of the following together:

- Being physically causally sustained (via causal pathways from a physical state of affairs or source.)
- Non-alethicity: having no alethic value, truth functionality, or bivalence associated with it whatsoever.
- Non-mathematical/Non-computational: having no statistical or constructed mathematical elements as necessary existential conditions.
- Anti-Platonist: having no reductive basis or existential dependence upon any Platonic and/or transcendental abstracta.

i.e. That the indication is I-indication: it is mind, language, computation, mathematics and theory independent in the sense that it necessarily does not existentially depend upon nor reduce to any of these ontologically. It existentially depends upon the causally-induced configuration of structures which are either identical to or else reduce to heterogeneous bounded regions of the quantum field, or upon structures which reduce to (or in some cases supervene upon [2].) Refer back to §1.3 p37 for the introduction of this important 'short-hand' abbreviation for The element of defeasible principles and theorising meta-metaphysically and methodologically applies even here, but in order to overturn, say, the non-dependence on mathematics condition (as Max Tegmark, or perhaps one of numerous pancomputationalists, seeks to do) would require serious contingent verification and demonstration.

Importantly, there are multiple naturalisations that can be either associated with the naturalisation of information and/or semantic information, identified with either, or taken to be their basis. They include, but are not limited to naturalisation of:

- Semantic content (Millikan, 2009; Fodor and Society, 1987)
- Representation(s) (Stampe, 1977; Godfrey-Smith, 1992; Stampe, 1986)
- Perceptual knowledge (Dretske, 1981; Dretske, 1988b)
- Beliefs or doxastic content (Dretske, 1988a)
- Structure
- Causation
- Concepts

Stampe was concerned with the naturalisation of representation on the basis of causal indication (Stampe, 1986, 109-11). There are other ways in which to naturalise representation commensurate with different degrees of liberal naturalism with respect to what can participate in the ontology, and with respect to different choices for the basis for a naturalistic conception of information. Devlin's approach to naturalisation of information has a situation theoretic basis, and calls into service the concept of the infon, which can be abstract. Devlin also deploys Dretske's concept of information as an abstract commodity, but he still regards hi approach as naturalistic, and Dretske is overtly naturalistic since his entire effort is based upon the naturalisation of information. Carnap and Bar Hillel had an overtly naturalistic disposition in developing their theory of semantic information. Dretske's project was to develop a naturalistic epistemology based upon a naturalisation of perceptual knowledge by way of something standing as an information theoretic alternative to justified true belief, which required naturalisation of information (using what was in fact an anticipation of scientific metaphysics [3]).

[2] The supervenience base must reduce in accordance with the defeasible identity theory. That is - it must be either identical to or else reduce to configurations of structured, bounded, heterogeneous regions of the quantum field

[3] There is very limited a priori conceptual analysis in Dretske, 1981

According to my approach, naturalised representations (naturalised according to causal indicative terms and causally induced configuration of structure) are not identical with information, but are encodings of information.

In the next section I will develop the conception of causally sustained indication as the basis of the intrinsic semantic content of I-CICS information.

5.4 Semantic Intrinisic Indication

I've argued that states of affairs as sources must be causal CICS structures to be informational. CICS Indication is something like Dretskian signal information intentionality. However, a very specific thing - label it ι - does the job of sustaining and making real the picking out of the indicated structures and states of affairs by the indicating structure(s.) ι is the set of physical spatiotemporal causal dynamical structures that constitute the total causal pathways between the causally upstream or precedent source structures and any causally downstream/impacted structure of interest.

Dretske allows that intentional information transmission (and informational representation) can exist based upon a virtual channel where a destination and source are correlated in terms of their structure. Causality is distinguished from information transfer such that the latter can occur without the former (Dretske, 1981, 41.) I take $\iota_{1...n}$ to be a set of $n \geq 1$ CICS pathways from the indicated structure in the world to the indicating structure(s.) Moreover, I suggest that the existence of $\iota_{1...n}$ between CICS structures is a *necessary* condition for CICS indication to obtain. If there are no such causal pathways then there is no real indication, nor transmission of information (consistent with Dretske, 1981, 76-7, 1988, 55-6.)

I suggest the semantic content of information is constituted of and reduces to causally sustained indication or indication along causal pathways - to $\iota_{1...n}$. The minimum semantic content of any information source is the indication that some concrete spatiotemporal causal state(s) of affairs (CICS states of affairs)- causally upstream in the causal pathway(s) - exist(s.) Both the causal pathways and original sources from which causal complexes or chains of cause and effect emanate and originate are $\iota_{1...n}$ indicated by, and are part of the semantic content of, any given CICS informational structure. At minimum their *existence* is I indicated. There does not have to be any informee with any perceptual, cognitive, or epistemic access to either the sources or the causal pathways.

ι indication is not some transcendent entity, nor some kind of quantity, nor reducible to a non-physical transcendent relational entity. Indication reduces to causal pathways (ιs), and these are I-CICS informational. The various upstream contributing concrete sources/states of affairs (including the causal pathways themselves) can be regarded as semantic-content (and information) contributing information sources. An information source is defined according to information science and communication theory as a stochastic physical process or a dynamical system, and more basically as a CICS structure.

Dretske has closely associated and even equated signs with indicators. I propose that signification is not type-identical to indication, largely because semiotic properties and other properties usually taken to be important to the obtaining of a sign are not a necessary condition for an indicator. I suggest that a sign is a sufficient condition for the obtaining of a structured rule-based or regular *signification* of some kind. CICS indication is not signification, and is not a sufficient condition for the existence of such a sign. However, indication is a necessary condition for it to obtain according to the CICS-FOSIR theory I am proffering. The existence of a sign is a sufficient condition for indication to obtain.

Dretske's conception of a natural sign is influenced by H.P. Grice's conception of natural meaning. Natural meaning is the meaning that obtains when the physical structure and accompanying properties of the physical symptoms of measles indicate the existence of a measles virus, or when the structure and properties of smoke means that there is a fire (Grice, 1957, 375-7.) Dretske proposed that natural signs have meaning because they are indicators:

> Natural signs are indicators, more or less reliable indicators, and what they mean is what they indicate to be so. (1986, 18.)

The semantic content of Dretske's natural signs - what they indicate to be so - is the material states of affairs and/or facts that caused them to exist or to be configured the way that they are, via ineliminable causal pathways.

Only indication is required as the reductive basis of all CICS informational semantic content - not sign-based signification where a sign is any kind of preconfigured, constructed, rule based, or even (physically) nomically regular structure. I suggest that there are different kinds of indication depending upon what about the upstream causal sources is ι-indicated: existence or else past existence (existential indication), and their *configuration* or arrangement (configurational indication. See below.)

5.4.1 Accidental/Coincidental Covariance of Structure is not Transmission

It is a necessary condition of the contingent FOSIR-CICS characterisation of I information is that it can be physically transmitted, and that this is a sufficient condition to adduce the I-obtaining of information. Covarying or correlated structures S^A and S^B with no intermediate causal pathways may contain information, but there is no information transmission occurring between them, and thus one cannot be about $*_i^\nu$ or otherwise represent the other unless the two are linked uni-directionally by other causal pathways: those introduced by an observer of both sources, for example. i.e. $\neg[(S^A *_i^\nu S^B) \wedge (S^B *_i^\nu S^A)]$, but $[(S^O *_i^\nu S^B) \wedge (S^O *_i^\nu S^A)]$ (common internal cognitive and perceptual structures of the observer O will be configured by A and B observations.) Note that transmission is not a necessary, but only a sufficient condition for the I obtaining of information. However, accidental covariance is not information transmission, and is not a sufficient condition for transmission.

An accidental formation in the sand on the beach that closely resembles the structure of one's face encodes and carries no information in, from, of, or at ($*_i^{\iota}, *_i^{\phi}, *_i^{\omega}$, or $*_i^{\alpha}$) one's face unless an observer of both the sand and the face is introduced (For notation refer back to §1.3.1 p41.) Placing one's face in a plaster mould does involve a causal encoding of information (the configuration of the plaster structure) from and of one's face.

Communication systems can involve virtual channels based on a co-variance between two structures, but such virtual channels always reduce to multiple causal signal-realising pathways. For example, source A may send a duplicate physical signal to receivers B and C so that the structure of the state of each receiver is similarly causally updated and configured. There is thus a virtual channel between B and C based on the structure of A and the signals it causes, even if there is no uni-directional direct causal pathway for carrying signals between B and C. Yet without the dual causal pathways from A to B and A to C, there would be no structural co-variance of B and C (Dretske, 1981, 74.) Causal pathways and causally sustained co-variance are ineliminable in information transmission.

There are no circumstances under which two accidentally co-varying sources S_{DR1} and S_{DR2} (or a source and a destination/receiver structure) can involve the transmission of I information. This is true even if both sources (or source and destination) are being observed via causal signal pathways by one observer S_0 - or in other words if there are causal signal pathways from S_{DR1} and S_{DR2} (see Fig §5.1 p191.)

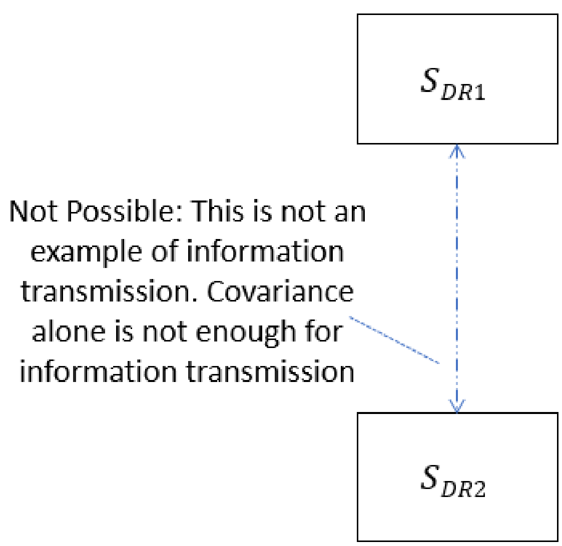

Figure 5.1: No CICS pathways, thus no signal pathways, thus no channel, therefore no transmission

In most cases the longer two sources are observed the less statistically likely it is that they will continue to accidentally covary. If there is some nomic causal constraint that persists the covariance, then that means that there is a high statistical likelihood of a common upstream source for the covarying and apparently causally unconnected structures/stochastic process/systems (that is - they are not really causally unconnected. see Fig §5.2 p192.)

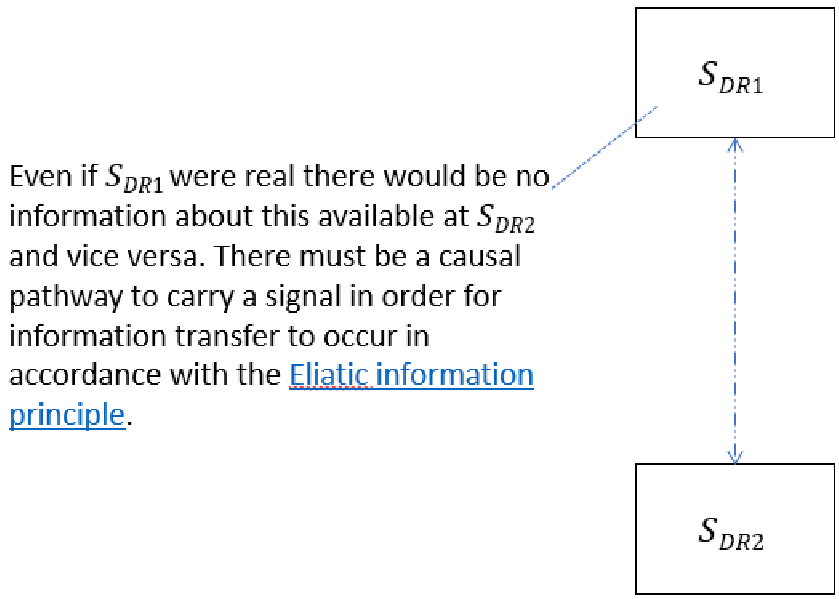

Figure 5.2: If S_{DR1} is Platonic the problem is worse.

If there is an observer of both sources, then the observer (if an epistemic agent) might get the impression that there is either a virtual or actual channel between S_{DR1} and S_{DR2}, but this is not made true by the reception of intrinsically semantic representing informational structures in the form of signals from both sources (see Fig §5.3 p193.)

If on the other hand the intrinsically semantic CICS structures are being transmitted in the other direction, then there is a possibility of actual covariance and a virtual channel if the signals are co-ordinated at the S_0,(see Fig §5.4 p194.)

5.4.2 Configurational ι-indication

The above presents a problem. It looks basic and uncontroversial that fruit flies A and B still naturally I ι-indicate something about each other's structures and CICS *configuration* and thus about each others' information. I will refer to this as *configurational* ι-indication. Configurational indication can be symmetric between the upstream causal source/structure and the downstream causally configured source/structure if both exist together.

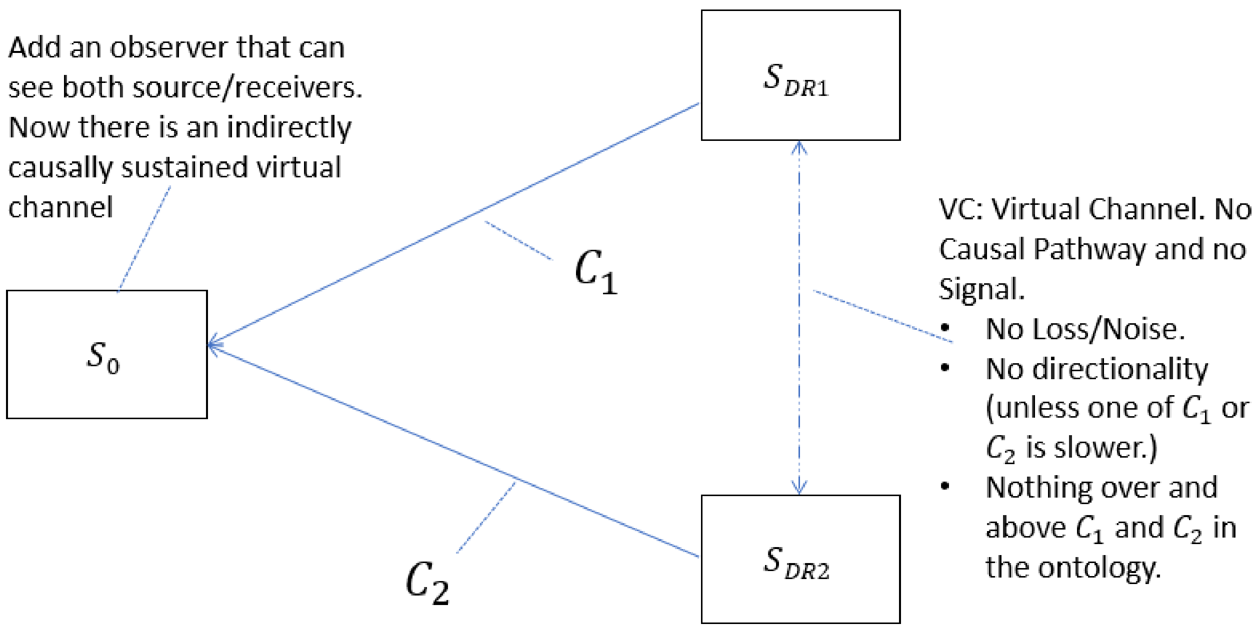

Figure 5.3: The addition of a receiving observer still does not result in transmission from S_{DR1} to S_{DR2}

Godfrey-Smith observes that Dretske's original (1981) conception of naturalistic semantic indication is unidirectional, and as such it is like existential ι-indication (285-88.) With configurational ι-indication, I suggest it does not matter what direction the causal pathways have, or how multipart and complex they are. Thus if A and B are carrots, and if C is a plaster cast of carrot A, C should indicate something about B even if B as a structured source is not in any of the causal pathways leading to C. This is because the common properties between A and B are sustained by spatiotemporal causal pathways involved in the evolution and distribution of carrot species genotypes. Thus both carrot A and carrot B are connected to each other by spatiotemporal causal pathways going back to the same ancestor carrot D, and both carry the same natural kind of carrot DNA/genes because of that causal heritage, and their causally induced structures reflect this (Various teleosemantic conceptions of information in the philosophy of biology rely upon something like this, but for representations. See Shea, 2007b.)

My argument is that CICS information is always intrinsically semantic by indication. Since existential indication does not always exist between sources indirectly linked by causal pathways (non-unidirectional in the case of fruit fly siblings), perhaps existential indication cannot be the right kind of indication to provide the semantic content of CICS information. Perhaps it should be

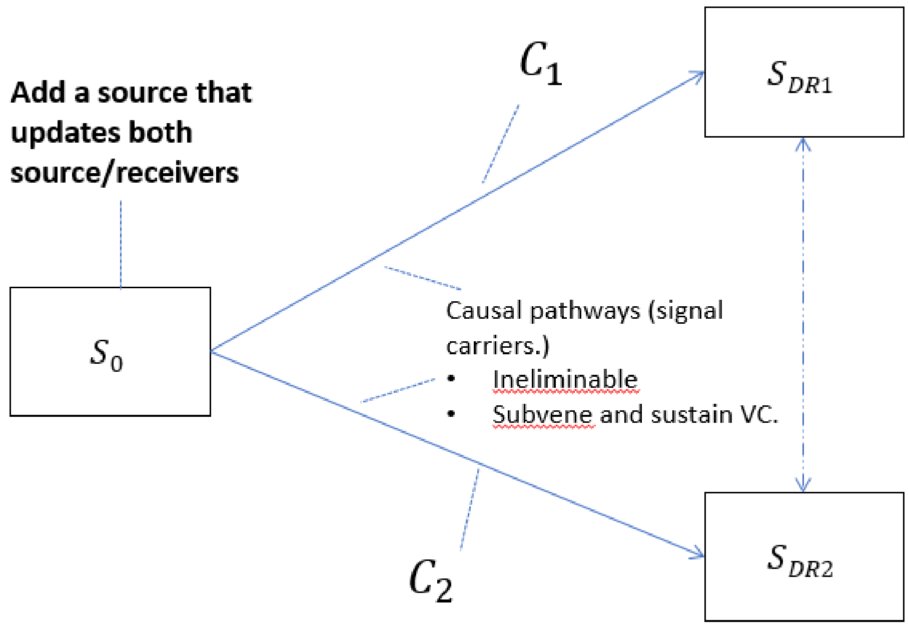

Figure 5.4: If a common source updates both destinations with the same signal then there is a virtual channel between the destinations

eliminated from consideration or even from the ontology. That is undesirable as it is the most basic ontic component of indication. The other move is to identify a different kind of $\iota_{1...n}$-indication as applying in the sibling fruit fly (common causal ancestor) circumstance: the ι-indication of *configuration* (configurational indication.)

Thus, according to the CICS approach, C does not *indicate* anything of B or of the structure of B unless either:

i. There exist causal pathways between B and C such that the structure of B causally induces some change in the configuration of the structure of C.

   or else, both:

ii. A and B have common causal origin source D such that their structures are mutually partially isomorphic due to D AND

iii. The kind of ι indication is *not existential* ι indication.

Causal existential and configurational ι-indication are I ontological simples. Each is sufficient to make CICS information intrinsically semantic, but only causal ι-indication is definable thus (S_0 (partially) represents S_1 by indication IFF there is transmission between S_1 and S_0):

$$(S_0 *^{\theta} \underset{i}{\Delta}(S_1)) \leftrightarrow (\underset{i}{\Delta}(S_1) *^{\sigma} S_0) \tag{5.1}$$

Correspondingly (this is a short digression which makes good use of our notation from §1.3.1 p44 for the purposes of clarity):

$$(S_0 *^{\theta} \underset{i}{\Delta}(S_1)) \rightarrow \Box(\underset{i}{\Delta}(S_1) *^{\sigma} S_0) \tag{5.2}$$

For $\iota_{1...n}$ indication, the indicated structure, causal pathways, and indicating structure all have to exist or else have I-existed. The *indicating* structure (at the end of the causal pathways) at minimum must still exist. Below I will argue that $\iota_{1...n}$ indication can be symmetric between the components of ι that exist simultaneously. If both upstream source structures, causal pathways, and downstream configured structures already exist (the sources and causal pathways may no longer subsist after participating in the causal pathways) the direction of the causal pathways does not matter for certain kinds of $\iota_{1...n}$ indication.

Take two structured entities A and B that are similar in structure on some basis. This could be by way of being of the same natural kind or of the same artificial origins: A and B could both be carrots, or quarks, or red giant stars, or pencils. If there is a third structure C whose microstructural configuration is causally influenced, affected, or induced by A, then C indicates something about/of (I prefer 'of') A - at minimum that A exists or did exist to participate in the upstream causal pathway. I will call this minimal ι-indication of present and/or past existence existential ι-indication.

By using some theory of universals and/or by identifying the importance of common properties shared by A and B, many philosophers would claim that C reveals something about B by way of indicating something about A. However, there is now an apparent problem. If resemblence or category membership is infdication, and all CICS information is intrinsically semantic on the basis of $\iota_{1...n}$ (causally sustained) indication, then it does not look like the information (per CICS) is always intrinsically semantic.

This is because it seems to be just wrong that a common causal ancestor D of A and B together with the causal pathways $D\iota A$ and $D\iota B$ delivers an I $\iota_{1...n}$ indication of *existence* from A to B or vice versa. In other words, in terms of *existential* ι-indication, it does not look like A existentially indicates B or vice versa. A and B do not each mutually I indicate that the other exists even in the case where all of A, B, and D and their adjoining causal pathways I-exist. The existence of B does not depend causally upon nor I-indicate the existence of A and vice-versa, even though they both existentially depend causally upon D. A and B both existentially indicate D, but not each other. D and the causal pathway $D\iota A$ are part of the indicative semantic content of A. Likewise for D, $D\iota B$, and B.

A and B can existentially ι-indicate structures upstream in the causal pathways only. Fruit fly A existentially ι-indicates a parent fruit fly D, but it cannot existentially ι indicate a sibling fruit fly B: the existence of one sibling fruit fly cannot ι-indicate the existence of another sibling fruit fly with a common causal (parent) origin. A response is that perhaps they can existentially ι-indicate each other by resemblance - or by covariance of their structures. After all, their structures are quite complex at both a genetic level (LoA if you like) and at the phenotype level, and the more complex and heterogeneously constituted in terms of natural kinds - such as different biochemical and macro-organ structures, the less statistically likely it is that they co-vary closely or closely resemble each other. In the next section I will attend to that response, and then proceed with development of the principle of intrinsic indication.

5.4.3 Representation

According to Dretske, natural signification/indication is a necessary but not sufficient condition for the obtaining of mind and language independent natural *representations* (Dretske, 1988a, 56.) Dretske's Type I and II representations are mind and language dependent and intentional, and non-natural in Grice's sense. Dretske reserves "the idea of representation for something that is closer to...Grice's non-natural meaning in which something can mean *that P* without *P*'s being the case." (Ibid.) Dretske describes Type III systems as natural representations on the basis that they have innate *I* natural indicator *functions*:

> Natural systems of representation, systems of Type III...have their own indicator functions, functions that derive from the way the indicators are developed and used by the *system of which they are a part* (Dretske, 1988a, 62.)

Critically, natural representation is different to conventional non-*I* representation because "in contrast to systems of Type II [for which the indicating function is externally determined by other systems including cognitive systems as conventional] the functions indicating what these signs represent are...independent of...extrinsic factors"(Dretske, 1988a, 62.)

Now according to Dretske a (Type III) *system of* natural signs can misrepresent (Dretske, 1988b, 68.) Moreover, natural signification/indication is only one necessary condition for a system of natural signs to be a representation. However, Godfrey-Smith notes that although Dretske has weaker and stronger conceptions of indication, it seems that he always "thinks of indication as requiring perfect correlation...there is no such thing as misindication" where the correlation is a statistical one based upon nomic constraints and background conditions (192, 289.) Natural lawlike regularities are also a necessary condition for natural indicating signs (and systems of signs) to be representations (Dretske, 1988b, 57-8.)

According to Dretske, truth is a necessary condition for information to obtain (Dretske, 1981, **45**, 46, 81-2.) Importantly, the indication relation is the relation that realises intentional information content of a signal (Dretske, 1988b, p58-9; Dretske, 1981, 43-5, 76.) Thus natural indication cannot be misindication, and so is effectively always true. It follows that there always exists information of natural indication. Signs (and systems of signs) with an innate *I* function of naturally indicating are false natural *representations* to the extent that they fail in their *function* to indicate depending upon lawlike regularities (1988, 68.)

I am claiming that in fact information does not require truth as Dretske asserts (Dretske, 2008, 29-31), but vice-versa. Moreover, innate indicating *function* is *not* a component of, nor a necessary condition for, the I CICS conception of natural representation.

I will denote I CICS representation 'μ-representation'. The necessary and sufficient condition for CICS μ-representation is a set $\mu_{1\ldots n}$ of $n \geq 1$ CICS causally sustained partial structural (configurational) isomorphisms between the features of the configuration of indicated structure(s) in the world and the configuration of the indicating structure(s.) That set of partial structural isomorphisms determines what is picked out from the configuration of the source/indicated structure(s) by the configuration of the indicating structure(s.) These mappings can be of any natural objective mind, language and computation independent kind, as long as they reduce to or themselves map to CICS causal pathways.

Therefore, according to the CICS account that I am presenting, the fact of the presence of configurational ι-indication is only one of two necessary conditions for natural I μ-representation - never a sufficient condition. The set of partial structural isomorphisms *and what they pick out is the other necessary condition.* It helps here to think mathematically. Both the (causally sustained) isomorphisms and those aspects of the configuration of the indicated source structure they pick out can be identified, labelled, and enumerated: they are each a real set of concrete entities. They answer the question "What is picked out from the configuration of the source structure by the configuration of the indicating structure and how?". Configurational ι-indication is just the fact of the existence of the isomorphisms. It answers in the positive to the question "*Is* configuration picked out from the source/indicated structure by the indicating structure?". μ-representation is thus the *content* of configurational ι-indication. They are not the same thing. Therefore natural (biological or otherwise) representing and/or signifying (Sarkar, 2005) structures construed as alethic cannot equate to, nor be a necessary condition for, causally sustained $\iota_{1\ldots n}$ configurational CICS indication.

Lawlike regularities are *not* one of the necessary conditions for either configurational ι-indication or μ-representation, even if they play a causal part in the governing of the causal pathways and partial structural isomorphisms. I've no space to expand here, but lawlike regularities result in a richer kind of natural representation than μ-representation. Neither are indicating *functions* a necessary condition for I μ-representation. It is Dretske's (functionalist) natural representations and CICS μ-representations both that are alethic in different ways. The information of configurational ι-indication is not alethic: it just exists as a set of partial structural isomorphisms.

5.5 Non-Alethic Intrinsically Semantic Information

According to the CICS conception and characterisation of semantic information it does not make sense to speak of information as either true or false. What does make sense is to speak of the presence or absence, or, more specifically, *the existence or non-existence*, of information. I am proposing that conceptions of alethicity and truth functionality do not apply to (CICS) information itself: only to CICS-informational natural I μ-representations.

Thus indication is not a sufficient condition for alethic value for information. Indication in representations reduces to the intrinsic indication - CICS information (existential and configurational.) Dennis Stampe has pointed out that there are certain requirements for naturalistic conceptions of representation (largely in the context of internal representations and propositions) and that " a causal theorist must provide the required reconstruction of the notion of a truth condition" (Stampe, 1986, 127.) According to the approach that I am articulating existential and configurational ι-indication are necessary but not sufficient conditions for μ-representation. μ-representations both indicate and represent, but clearly it does not follow that ι-indication and μ-representation are the same thing.

Existential ι-indication involves indication that a causally upstream structure exists *only*: it is the indication of a material fact or of the obtaining of a material state of affairs. It indicates nothing of the nature or arrangement of the causally upstream structure or source, except that it exists and is spatiotemporal and causal. *Configurational* ι-indication is the fact of the *existence of* a causally induced and sustained partial structural isomorphisms between the configurations of the indicating and indicated structures. It is also distinct from existential ι-indication because directionality of the causal pathways can be mixed, rather than unidirectional between indicating and indicated structure. CICS *μ-representation* is *what* of the configuration of the source structure(s) is in fact indicated - it is the partial structural isomorphisms and the information of the source structure(s) as induced in the indicating structure and what it picks out in the source.

The semantic content of CICS information is just the causally-sustained *I indication* of the upstream causal information sources: minimally what is I indicated is the existence of those sources. Consider the simple example of a coconut striking a mud bank. The presence of the indentation I indicates (minimally) the existence of the coconut and the event of its impact. Events are also spatiotemporal structures with causally induced configurations and thus they are information sources. The *configuration* of the causally induced structure - the indentation - is also an I CICS-informational *representation* of the configuration of the causally impacting or causally upstream spatiotemporal structure(s) (the coconut and the impact event.) Complexes of effects constituting signals and emissions (in/from machine communication systems and celestial X-Ray sources etc.) induce configuration of downstream structures like signals and energy emissions differently. Nevertheless, such causal inducement of the configuration of structures via causal pathways always produces causally sustained I indication and I representation.

Only the induced CICS *μ-representation* - the structural isomorphism(s) between coconut and indentation or between source and signal - has alethic value. The degree of isomorphism between the configuration of the coconut (and the coconut impact event, and so on) and that of the indentation is the degree of correctness of the representation (For a discussion of formal physical isomorphisms see Szudzik, 2010, 502-5.)

5.6 Pseudo-sources and Virtual Sources

CICS information sources implied to exist by fictional statements (statements about fictional entities) and putative (non-I) conventional representations of other kinds (pictures of unicorns) do not exist and therefore no real information exists in them. Representations of fictional sources are pseudo-informational: they imply the existence of real information at a real singular I source where in (material) fact there exists no such source. They are thus also pseudo-representations. Yet they are themselves physical spatiotemporal structures, and causally induced ones at that, and are thus information sources in their own right. They are embodied in CICS structures. It does not follow from this that either statements about or descriptions of fictions, or other putative representations of fictions, are not semantic on the basis of ι-indication.

I'll designate such implied but non-existent sources *pseudo-sources*. Semantic CICS information does not reduce to statements, syntax, language, representations, or messages (including mathematical statements or other constructs.) An informational representation of a Pegasus is both false and meaningless with respect to the implied pseudo-source. However, it has ι-indication based semantic content due to other causal sources: real horses, real wings, other informational representations of horses and wings and representations of fictional pegasii in the form of fictional descriptions and depictions (plus whatever other upstream contributing sources can be identified.) In other words, a whole set of upstream causally contributing CICS sources are indicated by the CICS (Pegasus) representation, but no actual singular I CICS source that is not a constructed fictional representation is in the set. In the CICS schema, I call such a set of upstream causally contributing sources that causally induce the configuration of a representation of a pseudo-source a *virtual source*. The configuration of a token of Quine's sentence "pink round square cupola on Berkeley College" is causally induced by a virtual source. The configuration of the structure of an image of a unicorn is induced by a virtual source. Pseudo-sources are not real, virtual sources exist.

Floridi agrees with Dretske's assertion that false information (misinformation) is not information but pseudo-information (Floridi, 2010b; 2011, 104.) It follows that pseudo-information is real - just not real(ly) information (Floridi, 2004a, p11-12; 2011, 104, 149.) According to the I-CICS conception, pseudo-information does not even exist: it is not in the ontology.

I am arguing that the specific information of one or more spatiotemporal causal structure-cum-entities (CICS structures) as sources are the semantic content for any structure(s) the configuration of which they have causally induced. The causally-induced configurations of those downstream structures (themselves sources and parts of sources) have ineliminable minimal semantic content by way of indicating something about the causally upstream structures (minimally, that those structures exist.) CICS information is a special kind of truthmaker, but not a truthbearer.

According to most semantic theories of information, information is somehow dependent upon and reduces to truth or truthbearers of some kind. In the section §5.7 p200 I will discuss the kind of truthbearers that Floridi and Bar Hillel and Carnap take to be involved. In the next section, I want to look more closely at virtual sources and pseudo-information.

5.7 Weakly, Strongly, and Intrinsically Semantic Information

Floridi's theory is intended to redress some of the problems with that of Carnap and Bar-Hillel, which Floridi labels The Theory of Weakly Semantic Information or TWSI. According to Floridi's alternative theory of strongly semantic information, semantic information is factual if it is comprised of data that is truthful according to the veridicality thesis. The veridicality thesis establishes truthfulness on the basis of Floridi's Tarski-inspired and Kantian correctness theory of truth, which I do not have room to discuss. The veridicality thesis states that semantic information must be comprised of information items (σs) comprised of data (δs) where the data must be well-formed according to some syntax, be meaningful, and be *truthful* Floridi, 2011b, 84, **104**.)

Weakly semantic information is realised by and reduces to sets of statements or - more precisely - formal state descriptions. They are the sets of possible formal state descriptions that describe possible states of affairs that do *not* obtain given a state description that describes a state of affairs that does obtain. The information in a sentence s is the set of all state-descriptions inconsistent with the state description that corresponds to s. In the case of data-centric strongly semantic information, the information content of state description regarded as an *infon* (σ) (a kind of information-atom) is the set of state-descriptions inconsistent with σ.

In the case of weakly semantic information truth (truth *values* in Floridi, 2011c) supervenes upon information (*semantic* information in Floridi, 2011b.) Floridi asserts that truth, veridicality, and truthfulness are synonyms in the case of strongly semantic information because they all mean "providing true contents about the modelled system" (2011, 105.) According to Floridi's conception, content must be data (δ.) Weakly semantic information, however, "is not meant as implying truth...a false sentence which happens to say much is therefore highly informative" (Carnap and Bar-Hillel, 1952, 229; Floridi, 2011b, 109.) According to Floridi this is a problem. It arises because Carnap and Bar-Hillel classify as real information what Floridi - largely following Dretske - calls pseudo-information. Floridi's response is to require that semantic information both have alethic value and be true only (Floridi, 2011b, 117.)

According to the *I*-CICS conception, alethic value is not required to distinguish information from pseudo-information. There is no real information associated with the range of the negation of a state description. This is because according to the CICS conception:

1. State descriptions do not constitute information because information does not reduce to any kind of syntactic description or statement whether constructed, formal, or transcendent (abstract): CICS information is *I* and non-Platonistic/non-transcendental.

2. State descriptions as formal syntactic structures (spatiotemporal syntactic rule-governed structures produced by mathematicians acting as or fulfilling the functional role of complex physical encoders) although informational, are only alethic as representations of other information (existing at causally upstream sources.)

The positive state description σ is a true (bivalently or else by degree - it does not matter) informational *representation*. Its structure has been causally induced by *I*-existing CICS sources. The negative formally expressed (constituted of physical spatiotemporal structures) state descriptions in the range of the negation of σ are just false informational representations when physically tokened. Thus, according to the CICS conception of intrinsically semantic information, neither the range of the negation of the state description nor the state description itself can constitute semantic information. Semantic information does not existentially depend upon state descriptions, only upon states of affairs (situations) or information sources where situations are spatiotemporal structures (Devlin, 1991, 69.)

Floridi refers to Carnap and Bar-Hillel's theory as weakly semantic because "there is no reference to the actual alethic values of the infons in question, which are supposed to qualify as instances of information independently of whether they are true or false" (Floridi, 2005a, 8.) This is what he calls alethic neutrality (AN): information (with the necessary condition that it is comprised of well-formed and meaningful data) existing independently of truth (Floridi, 2011b, 92.)

Alethically neutral weakly semantic pseudo-informational infons (σs) can be meaningful without being true, but their lack of truth - via the veridicality thesis and a lack of truthfulness of their constituent data - renders them non-informational (2011, 81, 98-103.)

Such pseudo-information is "no information at all...only meaningful and well formed data, namely, mere semantic content" (104.) It is not clear how data are meaningful, since this cannot be on a truth-functional basis using the veridicality thesis. The veridicality thesis delivers the *truthfulness* of data - not their meaningfulness. It does then seem that strongly semantic information requires no truth for data to be semantic, but requires truth for information comprised of data to be semantic. It does seem that items of strongly semantic information would already be semantic by virtue of being comprised of meaningful data, without any need for veridicality. Moreover the semantic content of information seems to be overdetermined - or dually determined, and that perhaps even a circularity threatens. Data is already meaningful, but information comprised of information items comprised in turn of data are meaningful because they encapsulate.

Floridi identifies σs with state descriptions in Bar-Hillel and Carnap's theory (2005, 8.) However, it is not clear what the data δ that Floridi elsewhere takes to comprise items of information (σs) correspond to. It seems that they could correspond also to state descriptions - those in the range of the negation of the positive state description that Bar-Hillel and Carnap stipulate constitute its semantic information content. This would fit with the Kantian transcendentalist conception of information that Floridi espouses if the state descriptions of the possible non-obtaining states of affairs are transcendent. In this case however it is arguable that the data are only transcendant descriptions of possibilia. My ontic charge is that such cannot constitute a basis for any real information. Moreover it is not clear how such possibilia are also relata of any kind - transcendental or otherwise.

In any case, Floridi rejects the idea that semantic information can be false as Bar-Hillel and Carnap assert. He requires that information is necessarily true only by correctness of data included/encapsulated within the infon(s) comprising the information.

According to the I-CICS account, Bar-Hillel and Carnap's theory of semantic information is really a theory of semantic syntactic formal non-I *representations* of information. Such representations are syntactic symbol-sequence structures, and are thus informational when expressed physically and syntactically. Like any other informational structures, such syntactic expressions have a causally-induced configuration. In the constructive case - where state descriptions are only formal a-posteriori synthetic constructs (conventional encodings of information) - this involves complex mind-dependent syntax.

It does not seem that Bar-Hillel and Carnap could admit of real state descriptions as transcendent and a-priori, given Carnap's formalism and physicalism. This seems especially true where there are only possibilia to be described. In either case - both constructed tokened and transcendent a-priori state descriptions - they are not comprised of the information that they *represent*. According to the I-CICS conception representations are CICS structures. Thus they are semantic because they are comprised of source-indicating structure: the indicated sources can be actual or else virtual (comprised of actual sources.) The existence of a representation is not a necessary condition for ι-indication to obtain and thus not a necessary condition for CICS structures to be semantic. Thus the state descriptions of Carnap and Bar-Hillel's theory are not semantic *information* content. They are syntactic language-dependent CICS *representations* of information and pseudo-information. Representations are alethic. Information isn't.

Truthful data comprising Floridi's strongly semantic information can somehow exist transcendentally in non-extended noetic and Platonic spaces. Thus the range of the negation of a true state description on Carnap's formal terms is prospectively comprised of relational differences and data (δ) in non-extended spaces that can or could constitute real information. According to the I-CICS theory of semantic information, however, information does not reduce to atomic data of any kind, but to the configuration of I-CICS structures. There is simply no actual information indicated by the range of the negation of a state description if it is not physically tokened. When physically tokened or expressed, the total structure is a representing CICS structure the same way as the positive description token is. Real information can not reduce to a set of possible states (of the universe/world or of a source) that could obtain, nor to the objective or subjective reduction in uncertainty associated with the obtaining of the actual state of affairs or state of the source (or of the universe or state of affairs taken as a source.)

It might follow from the existence of a certain CICS structure that it does not exist as some other possible structure, but this is not what constitutes information according to the I-CICS conception of intrinsically semantic information. Biting the physicalist and non-transcendental bullet for information - sets of possible structures or possibility spaces somehow comprised of the same are not informational. Even if they are considered somehow to be I, they cannot be CICS. Probabilities *might* be CICS (frequency data or physical propensities of some kind) but probabilities are not possibilities. At a stretch, we could regard possibilities as physical frequentist event sets to make them CICS, but this is very radical. Such sets of events would be CICS information sources in their own right, and it would be their collective virtual source configurations that constituted the information. It is not clear how possibilities as we normally consider them would fit with this picture.

Floridi's conception is Platonist or transcendental since Platonic and non-extended entities can comprise data and are therefore informational. With the requirement that the data to which semantic information reduces must be both true and syntactically meaningful in place, Floridi's semantic information must be or becomes a kind of truthbearer. Semantic information itself has alethic value: it is always necessarily true.

The common feature of different representationalist conceptions of information including both strongly and weakly semantic information is that information exists as or reduces to message structures and constructed syntax of some kind used to produce them. According to the I-CICS conception of information, such structures are only representations of information, or else pseudo-informational representations if they do not represent any I-CICS information sources.

5.8 Conclusion

I have provided a conception of intrinsically semantic causally induced information that explains how the semantic content of concrete sources (actual information) and pseudo-sources (virtual information) obtains, but the most salient outcome that I hope I have demonstrated is that even fictions that are in some cases thought to be Platonic must reduce to physical information sources at some level - or else they will naturally necessarily not involve any information at all.

Recapping, according to the I-CICS conception:

1. Information is intrinsically semantic because of causally sustained indication, and
2. Information is not alethic, and
3. Information is not comprised of, nor does it reduce to or supervene upon data or any relational entities - especially transcendent relational entities.
4. Pseudo-information is not only not real information, but does not really exist: there is no pseudo-information in the ontology because information either exists or it does not.
5. Informational representations can be pseudo-informational, not because pseudo-information exists, but because they imply the existence of I CICS sources of information where no such sources exist: they ι-indicate virtual sources and represent pseudo-sources.

I've argued that we should dispense with the idea that information has alethic value, and also no special separate additional theory and conception of semantic information is necessary or desirable. In a very real sense, information *is* the alethic value of any representation that encodes it. According to the conception and theory of intrinsically semantic ι-indicative I-CICS information, all CICS structures are semantic by *indication* along causal pathways alone - that is by virtue of the existence of causal pathways from I-CICS information sources.

I have argued that the way to deal with the problem of informational but false state descriptions is not to require information to have alethic value, but instead to recognise that information is not and does not reduce to the kind of thing that has alethic value. According to the I CICS conception to think of information as true or false is a category mistake. Instead of asking whether information is true or false, the correct question is whether or not there is or I exists information. According to this approach, information is a special truthmaker. Information does not reduce to mathematical or other mind, language, and representation *dependent* constructs like statements, nor to any kind of abstracta such as state descriptions of possible ways the universe either is or is not.

Information is not a syntactic truthbearer that could even be false (or true in the sense of being veridical or corresponding to something) in the first place.

The problem of informative false state descriptions is instead a problem about representations only because semantic information is not what Bar-Hillel and Carnap said it was. Shannon's conception of a possibility space of possible states of a source constitutes a measure of information - not information itself - which according to Shannon's theory requires an actual physical source and source states.

Bar Hillel and Carnap's and Floridi's conceptions are inadequate as theories of semantic information. They are instead theories of strongly and weakly semantic *representation*. The informational ontologies of weakly and strongly semantic information are different enough to suggest that almost any alternative is permissable. I have suggested the physicalist I-CICS theory of information is simultaneously a theory of intrinsically semantic information.

Chapter 6

The QFT-Structure Identity Thesis

6.1 Introduction

This chapter brings my work with QFT based field ontology and source ontology closer to work done by other philosophers of information in the context of what are sometimes called informational structural realisms. My revision of NOSR will be further developed here. I present further development of, and argument for, the scientific metaphysical identity thesis of CICS structure and selected structure inhering *in re* in the quantum field/vacuum, where I take the quantum field to be I-obtaining according to the definition at §1.3 p37.

I will then evaluate the ontology that this delivers with reference to the NOSR of both Ladyman and Ross, which I will argue is inherently information-theoretic by dint of its deference to I-obtaining stochasticity as well as Ladyman and Ross's own earlier references to information channels as necessary to scientific realism, and to the NOSR of other ontic structural realists (Michael Esfeld and Vincent Lam, Simon Saunders) and philosophers of information (Luciano Floridi.)

I will further develop the idea of eliminativism about relations as ontologically prior to structure, and thus turn most OSR 'on its head' by different means to that deployed by Ladyman and Ross and Steven French. I'll regard not only properties and relata, but also relations, as features of structure - not its basis (see especially section §6.6 p242.) My view is that this is the best candidate for explaining the nature of the structure which ontic structural realism is realist about on a scientific metaphysical and contingent basis. Thus, this is further support for the identity argument (H2) and the source ontology argument.

The overall argument that goes with the identity thesis is that information exists in the ontology of the world intrinsic to CICS and is not just an artifact of theory and modelling. To achieve this I use induction and deploy and further develop the indispensability argument according to which reference to information (or else to I-existing features that involve transmission, encoding, or generation) is in many scientific theories as indispensable as references to structure or patterns. Daniel Dennett is not a reductionist about what he has called real patterns (Dennett, 1991. See my discussion below at §6.3.2 p221), but one way of summarising my argument and proposed metaphysics is that such patterns necessarily realise information and are ubiquitously referenced and represented in scientific theories because they are ubiquitious in the I-ontology about which the scientific realist is realist.

I will proceed by first (§6.2 p208 and §6.3 p213) discussing Luciano Floridi's influential and important conception of infon-reducing data having an existential basis in *de re* nonuniformities, and compare this to my own FOSIR-CICS approach for the ontic basis of information.

6.2 Nonuniformity and Heterogeneous Fields

In this chapter, reference to *the* quantum field is reference to what physicists call the *universal* quantum field. The scientific metaphysics of information I propose requires that information existentially depends upon the existence of, and ineliminably reduces to, the causally induced configuration of I-obtaining physical structures. The structures in question are construed according to a very specific physicalist and reductionist NOSR (where the R is about I-obtaining structures) motivated by scientific realist scientific metaphysics such that they either are or else ineliminably existentially depend upon and reduce to non-uniform/irregular physical structures, which in turn reduce to (or - defeasibly - are identical to) *heterogeneously constituted* classical fields and bounded regions of the quantum field (Cao, 2003b, 63; French, 2014; Cao, 2003c, 4, 16, 18) - in the physical sciences. The nonuniformity in question is nonuniformity in an I-obtaining physical structure or a structure that reduces to I-obtaining physical structures that reduce to heterogeneously constituted fields.

Informational structural realisms have been proposed before, but not specifically as field ontologies, although there have been efforts to reconcile NOSR with QFT (Cao, 2010, 204.) I am also not original in identifying non-uniformities as the reductive basis of both structure and information. Floridi does this with his ontologically neutral data/non-uniformities (Floridi, 2004a; Floridi, 2011c.)

Floridi's metaphysics of information is not physicalist, but is reductive. Floridi reduces semantic information to data, which he defines as nonuniformities constituting difference relations at minimum. Floridi's diaphoric non-uniformities *de re* - or data *de re* - are one of three diaphoric non-uniformity based data:

I. *de re* : I abstract, constructed, and natural (but not physical), as with non-uniform fields. Includes what I refer to as physical *in re* non-uniformities (Floridi, 2011c, 83-4; Floridi, 2009b, 15-17.)

II. *de signo* : I natural and constructed contrasting states.

III. *de dicto* : *I* natural and constructed contrasting symbols.

(II) reduces to (I) according to Shannon's theory and the definition of sources as stochastic processes, and as dynamical systems according to more recent mathematical communications theory. This conceptual and ontological reduction of (II) to (I) is also compatible with a four dimensionalist view of the universe, which is compatible with contemporary quantum mechanics and cosmology in physics due to Minkowski's spacetime model, which is also deployed broadly in QFT - both in its Lagrangian and algebraic manifestations (Swanson, 2017, 204, 215.) This maps to the idea that information in *I* natural sources in science is encoded into other *I* obtaining structures. Complex encoding (which includes, among other things, neurologically reducing physical information processing sources) delivers constructed CICS reducing representations.

(III) is important to the symbol grounding problem (Taddeo and Floridi, 2007), but in the natural case also reduces to (I) as in the case of *natural syntax*. Floridi explains the concept of non-linguistic syntax as that involving libraries of symbols, pictographs, and such (Floridi, 2011c.) The idea of natural syntax follows easily from this and from Shannon's theory, according to which continuous, analogue, stochastic information sources involve alphabets of such things as waveforms (Shannon, 1998; Gallager, 2008, 16, 71-2, 85; Orlitsky and Santhanam, 2003; Hayashi, 2017, 599.) My approach applies ontological reduction to both *de signo* and *de dicto* uniformities, reducing them to complexes of *in re* non-uniformities. According to the physicalist CICS approach that I am proposing, there is no such thing as a non-physical, non-causal, transmission and encoding incapable information bearing or informational non-uniformities *de re*. All differences *de re* reduce to non-uniformities in re, but not vice versa. It is important to understand that a non-uniformity or structural feature is not the same type of thing as a difference, although it may incoporate a difference. Floridi discusses differences *de re* and non-uniformities *de re* as if they are identical concepts (Floridi, 2008a, 234-6, 247.) Yet, differences do not have to be part of the same structure. There is a basic logical and categorical difference between a frog and a quark, but we would not readily think of this as a structural nonuniformity. I think that this confusion/conflation of difference with non-uniformity partly arises from discretising (including digital/binary) data centric metaphysics. Floridi eschews digital ontology, but in a sense retains it in the binary of non-uniformities *de re* that become more like differences *de re*. Floridi analyses non-uniformities as binary differences *de re* since he asserts a-priori that "in its simplest form, a datum can be reduced to just a lack of uniformity, that is, a binary difference, like the presence and the absence of a black dot, or a change of state, from there being no black dot at all to there being one." (Ibid., 236.)

Floridi is aware of the metaphysical quandry he faces in reconciling differences *de re* with differences *in re* (concrete):

> if a datum is a difference, then a datum is an abstract thing, as a difference is an abstract, rather than a concrete thing. But this raises

> a severe problem, if data are supposed to be the basic objects in our structural realism (assuming that this is supposed to be structural realism as a possible position in philosophy of science). For the structural objects need to be concrete things in the world ... you cannot make concrete things out of abstract things, so informational objects do not seem to be viable candidates for the objects in an ontological structural realism fit for the philosophy of science. (Ibid., 247)

I think Floridi fails to overcome the problem identified in his last sentence above, as judged by scientific metaphysics and information theory. His response is to attempt to accommodate both kinds of difference under a transcendental schema. Note that his metaphysics is not scientific, since he classifies science and philosophy in the same category w.r.t empirical coherence and quality:

> ... [I]t is true that no concrete things can come out of purely abstract things, at least not without presupposing some metaphysical superpower that science (and its philosophy) had better leave alone, if they can. However, no reason has been offered to justify the view that data, understood as differentiae *de re*, may not be as concrete as one's definition of "concrete" may allow... Now, the correct position is somewhere in between: as far as the argument in favour of ISR is concerned, data are neither purely epistemic (abstract) entities... nor ontic (concrete) differentiae *de re* inseparably coupled to some epistemic component, as suggested by objection (6.8). They are (or need to be treated as) ontic (concrete) differences that are then epistemically exploitable as resources, by agents like us, for their cognitive processes. (Ibid.)

Among other things, remarkable here is that there is a strong subjectivist justification - requirement in fact - for the characterisation of data. At the same time, there is an anti-platonist view, in keeping with the transcendentalist framework.

> [T]he data/differences in question can be concrete because we do not have to assume something as radical and problematic as Leibniz's ... monads: Eddington's package hypothesis (cVr-relata + c7r-relations) is sufficient to support OSR. Second, it should therefore be clear that the interpretation of structural objects as informational objects is not meant to replace an ontology of concrete things with one of virtual entities... OOP provides us with an interesting example of how we may conceptualise structural objects and make sense of their ontology... talking of concrete differentiae de re, and conceptualising them as data structures and hence as informational objects, we are defending a version of structural realism that supports at least an irreducible, fundamental dualism, if not a Leibnizian pluralism, as the correct description of the ultimate nature of reality. (Ibid.)

Here Floridi avoids what French would likely identify as mathematical collapse, yet calls object oriented computer programming (OOP) into metaphysical service and thus delivers the same outcome via a theory of software systems modelling. Abstraction in software engineering may be the relevant kind of abstracting-out or abstracting-away-from kind of abstraction, but in software systems modelling this applies to anything (abstracting away from the details of the fictional beings in the code for a fantasy role playing game, for example.) In OOP, it is frequently the case that engineers abstract away from - other non-concrete abstract objects or structures (It should be noted also that in software development and engineering, and object in code and a data structure are two categorically different things.)

In trying to avoid a reductive ur-concept for information, Floridi largely delivers one in a transcendental framework. I suggest that differences *de re* are not the same thing as non-uniformities *de re* (the set of all of the the former is not identical to the set of all of the latter), and even if they were, the "cohering cluster of data" that Floridi builds from them using a-priori conceptual analysis does not get us to a coherent metaphysics of information. For that we need a scientific contingent metaphysics. I suggest that instead of coherent cluster of *de re* difference data, what is required is a set of signal (causal pathway) connected CICS information sources that can itself be regarded as an information source. I agree with Floridi's assertion that as an a-priori analytic formal construct " the relation of difference is binary and symmetric" (Ibid., 236.) Floridi's conception of non-uniformities is binary and reduces to *de re* differences, and I think that the basis for the formulation is clearly both a-priori and confused. I recommend that, instead, informational non-uniformities always reduce to *in re* non-binary features of physical structures which reduce not to relations, but to fields. I develop this biting of the bullet identity thesis between structure and fields fully in chapters three and four.

According to the CICS based conception, and the adapted NOSR - which I am calling ontic structural informational realism or OSIR - that I'll attempt to derive from or base upon contemporary physics, (II) and (III) both reduce to *in re* non binary non-uniformities, and the only real information is that which reduces to physical non-uniformities *in re* which constitute minimal information sources, which also incidentally allows us to deal with dynamical non-uniformities. When considering what it could mean to say that (III) reduces to (I), one easy route is to consider that some natural structures are elements of naturally occurring lexicons of syntax: the sequences of DNA and RNA for example. Such symbols and syntax *I* exist. This is not very controversial except for the challenge from subjectivism about information.

6.2.1 The Symbol Grounding Problem

What of constructed symbols: Charles Sanders Peirce's symbolic signifiers? How can they be reducible to natural non-uniformities *in re*? Put brutely: it's not elegant. However, elegance is not a prerequisite for truth or correctness. Such *in re* reduction involves brains, brain based physical information processing, cognitive transmission by linguistic encoding [1], and other symbol/message (in the classical non-semantic Shannon sense) transmission mediums all reducing to I-obtaining physical structures and information (with the shortcut physicalist reference that physical structure is a necessary and sufficient condition for the I-obtaining of information.) Pragmatism is certainly a component of scientific method, and it demands a lot of abstracting-out/away of information (a lot of wilful information hiding.) If we want to know about the entire information of the system, however, we have to undo this, and especially if we want to know about the nature of structure and information themselves. The requisite necessary and sufficient condition for the obtaining of any kind of symbol is signal/emission based transmissability or transmission, where signals and emissions are physical causal pathways recognised contingently by science as manipulable, realisable, and/or measurable. Any complaint that this condition for the obtaining of informational symbols is either arbitrary, not contingent, or unnecessarily restrictive, must be accompanied by a demonstrable way of realising information transmission in the absence of a physical channel and signal/emission, or information generation in the absence of a stochastic ergodic or non ergodic causal and physical source.

Symbol grounding then arguably presents a problem only if one does not admit of the possibility of a reductionist and causal explanation for semantic content: one that involves semantic content reducing to causal indication of upstream causal CICS sources where cognitive symbol recognition operates by the same mechanisms but with physical information processing introspection of neurological sources to sustain mental representation, for example. This very reductionist approach to semantic information does allow for a supervenience relationship between structures at a higher (Floridian computer-science inspired) level of abstraction and those at lower LoA. The reason for this relaxation of reductionist premises is epistemic access: the causal inducement relations may simply be practically (but not in-principle, except in the case of some kind of naturally necessary impediment) inaccessible. I propose an encoding mechanism that does not have to be troubled by any issues related to a philosophy of mind per French's re-iteration of Rosen's concerns about how representations are realised:

> Thus, one way of grounding it is to appeal to some process of abstraction, so that we begin with concrete entities and obtain, somehow, via this process, abstract entities by (of course) 'abstracting away' certain features of the concrete. However, the nature of this process is either unclear, or involves problematic features, having to do with the particular philosophy of mind assumed in talk of 'obtaining' abstract entities (Rosen 2001) (French, 2014, 198.)

I contend that there are not really any seriously problematic features of this process in-principle. What is trivially problematic - ergo French's appeal to

[1] I am not referring here to the literal scientific conception of (natural) transducer-based encoding except as a low level neurological partial basis for natural language use

'some process' - is epistemic access to the minutiae of the mechanisms, in, for example, the case of the neurological underpinnings of internal representations and the encoding thereof (a CICS-source conception of cognitive information sources is effectively tantamount to a representational theory of mind), and of the many neurological mechanisms also involved in rendering external in-theory representations based upon them (not least of which are whatever mechanisms turn out to be the underpinnings of natural language processing.) This really reduces to a (very large) complex of encoding (at various levels of abstraction) and transducing (at a very low level) processes (including associated stored rules.) Such can be regarded according to the very same abstractive and interpolative basis of interest. In this manner a scientist and their methodology and instruments can be regarded as a representation-encoding black box. The encoding processes at higher levels of abstraction and across levels of abstraction (since in the case of natural systems especially, levels are themselves imposed arbitrarily or else related to natural function and properties) might involve posits, trial and error, confirmation, instrument and theory calibration, and interpolation - at minimum. Critically, and according to the thesis and metaphysics I am presenting, the complex of processes depends upon Constructive processes are included in this. Just because constructive invention is used in determining the appropriate structure/features in the I-structure to isolate and abstract out, it does not follow that this does not constitute an abstracting of information out from the total structure of the natural phenomena or systems. I will have to leave further development of this idea a promissory note for the most part due to space, but I will add that regarding cognitive processing of information as being processing of *physical* information helps with a very large part of the puzzle.

6.3 Reduction to I-Regions of The Universal Quantum Field

Luciano Floridi, in his stated aspiringly non-reductive approach to the nature of information, is interested in applying the principle of levels of abstraction that is familiar from computer science to demonstrate that not all information is reducible. I say aspiringly, since in the process of formulating both a theory of semantic information and an informational structural realism, he nevertheless proposes a thoroughgoing informational ontology according to which it is information that is at the ontic basis not only of the scientific image but of material reality (Floridi, 2005b.) This latter very much seems to be a case of ontic reduction.

Other reductive and non-reductive physicalists have spoken of explanatory levels and emergent properties, and of levels of reality (Dennett, 1991; Mitchell, 2009; Wimsatt, 2000.) Non-reductive physicalists like Chalmers often endorse supervenience and emergence. Like Ladyman and Ross I will broadly reject the idea of ontological levels, levels of reality, or levels of physical explanation as I-existing in the material world and as something that is instead isolated epistemically by the encoding abstracted-out information into representations. According to Ladyman and Ross, such levels are only apparently represented. They are in fact imposed epistemically and as formal constructive artefacts, but do not really I-obtain in the physical world (Ladyman et al., 2007, 56-57.) According to my approach they can be thought of as epistemically imposed selections of features (encoded) from the entire structure of a system (refer to the no abstract wireframe principle §3.3 p101 and §2.3 p62)

I agree with the rejection of 'levels physicalism' also for both I-obtaining structure and I-obtaining information. Unlike Ladyman and Ross, Chalmers, and Floridi I do not reject physical reductionism, since I think that causal continuity, informational closure, and primacy of physics constraint (PPC) together with no miracles argument entail I-reducibility of all informational natural systems, even if the accessible information is partial and the rest of the information is *practically* epistemically inaccessible. There is no in principle nor any contingent reason why reduction of sources defined as bounded continuous and discontinuous regions of multidimensional fields to other sources of the same kind can't be a reduction of scale (micro-reduction) and may be a reduction to other physical natural kinds in some circumstances. This follows from and/or fits with the classical and more contemporary physico-mathematical definitions of sources as stochastic physical processes, and more recently as physical dynamical systems modeled as mathematical dynamical systems(Gray, 2011a, 1, 5-6, 10-11; Gallager, 2008, 5-7; Shannon, 1998, 5.)

6.3.1 The Contingent Defeasibility of Theoretical Physics

With respect to the defeasibility of physics, still in keeping with the primacy of physics constraint (PPC), the Quantum field may contingently turn out to actually reduce to some other natural kind (Weinberg, 1995a, 499; Cao, 2010, 210-15; Swanson, 2017, 2, 4, 6; Esfeld and Lam, 2009; Esfeld and Lam, 2008; Esfeld, 2013; Ladyman and Ross, 2013, 135; Fraser, 2004b; Teller, 1995.) Defeasibly, for my purposes, however, it is structure and therefore bounded regions of fields (reducing to the quantum field) all the way down (or down as far as physics currently goes), or to be more accurate to the ontological and conceptual domains, all the way in or out (for some initial insights, see the conclusion of Arageorgis, 2013.) I suggest this is the best available approach to cater for the strangeness of both quantum superposition states and quantum non-local effects or entanglement. It does not involve ignoring the best quantum science in the shape of the experimental proof of the Bell inequalities in 1971 and 1984 (Aspect et al., 1981; Bell, 1966; Clauser and Shimony, 1978; Esfeld, 2015; Hensen et al., 2015.)

I am not postulating - without any consensus support from physicists - that fields somehow stand in as the missing intermediary or causally mediating hidden variable structures that Einstein insisted must exist to account for and explain entanglement (Esfeld and Lam, 2009; Esfeld, 2013; Esfeld, 1999; Ladyman and Ross, 2013, 135; Arageorgis, 2013, 212-213; Bub, 2005, 543-6.) Especially in the light of the above cited Bell theorem experimental proofs and accompanying no signalling theorem.

The Bell inequalities and experiments for non-locality not only do not necessarily, nor in-principle, undermine PCC. This is because, whatever the nature of the causal pathway that is involved can be assumed, without concrete positive ontological evidence to the contrary, to obey PCC. In other words, the falsity of PCC doesn't necessarily follow from the fact that the specific cause of non-local effects in entanglement is not currently catalogued, nor even detectable. Such has not been a reason to conclude that there exist non-physical substances or existents that can sustain a causal pathway. One reason that this is apparent is that entanglement evidently involves, and obeys, constant natural nomic constraints. To conclude that PCC is false requires clear repeatable positive experimental evidence of interacting entities (hidden variables, for example) that are demonstrably not operating per PCC and ICP (ineliminability of causal pathways §1.3 p37). In any case, using the definition of *I*-existence as stated (§1.3 p38) as a set of necessary conditions for the way in which information would have to exist in order to satisfy scientific realism is not at odds with a contingent scientific metaphysics.

I *am* saying that the best current physics demonstrates that two quantum systems of like types (photons, gluons, muons, quarks, or electrons, and so on for the entire standard model) will be qualitatively the same no matter where in the known cosmos (where nomic physical constraints are known - contingently and defeasibly - to persist as universal) they exist. My approach can tolerate contingent discoveries that undo this, since I include defeasibility as an element of scientific metaphysics precisely because it is an element of science and especially theories in physics. Moreover, currently (according to our best physics) two (or any number of) entangled particles can be regarded as one information source, and so can regions of the fields at which they are each quantised be taken together as one information source (Bynum, 2014, 131-35.) The discovery of the Higgs Boson in 2012 presented physicists with a problem: it obeyed the standard model, and thus must itself be explained by further underlying physics. String theory considered at best a possible close defeasible alternative pending contingent confirmation - since there is no experimental physical evidence whatsoever for its truth to date.

The locus classicus example that bears out this defeasible theorising and ontological disposition of physics, and its predictive power by way of encoded representing structures, is Wolfgang Pauli's postulation of the existence of the neutrino (relabeled as such from Pauli's original and now ambiguous 'neutron' by Enrico Fermi) to account for the excess/missing energy and corresponding failure of his equation about energy exchange in a photon-electron interaction to balance (Cowan et al., 1956; Guerra et al., 2014; Reines and Cowan Jr, 1953.)

Pauli found that - according to the physico-mathematical equation, electrons were carrying off less mass than expected in β decay in the electron photon interaction according to physics' central tenet of the conservation of energy, leading him to postulate that another particle must to account for the rest of the mass-energy in what he called a "desperate remedy" (Guerra et al., 2014, 1351):

$$v \bar{-} e + p \rightarrow e^{+} + n \tag{6.1}$$

(Kim et al., 2013)

After initial experiments in 1953, Frederick Reines and Clyde Cowan Reiner experimentally demonstrated the existence of neutrinos as the mathematics and physical principles together had predicted in 1956 (Kruse, 2011; Cowan et al., 1956.) By 1958, Maurice Goldhaber, Lee Grodzins, and Andrew Sunyar at Brookhaven National Laboratory determined that the neutrinos have specific physical properties such as lefthanded helicity or anti-clockwise spin in the direction of their motion. The physical phenomena predicted by mathematical modeling of physical principles revealed turned out to be real extended physical phenomena/entities. No such conclusion or outcome is thought to be available for the mathematical entities employed in the theory.

Another example is the recent experimental confirmation of Einsteins theory of general relativity by means that Einstein himself never expected to be possible, declaring that "their magnitude [frame dragging effects of large spinning celestial masses on gravity] is so small that confirmation of them by laboratory experiments is not to be thought of" (Einstein, 1950.) I think that information in empirical theory formalisms is realised as representations that also reduce to CICS, but that their semantic content comes from the encoding of intrinsically semantic (on a causal indicative basis) information at multiple levels of abstraction. Stephen Hawking's theory of the informational properties of a black hole and event horizon provides good support. There is doubt about the correctness of the theory, but the terms of the theory are not in question with respect to their referring to material entities and I-obtaining structure(s) and other elements including information in information sources.

I think that this remains true for several interpretations of the nature of information, and especially wherever the accompanying metaphysics is physicalist: arguably a working assumption of most science. Varying commitments to reductionism might constitute a degree of freedom between physicalist theories and/or scientists (Mitchell, 2009, 21-23.) However, I will be arguing that in important ways information is and reduces to specifically physical structures, and that the best applied sciences of information bear this out through their conceptions and definitions of channels, noise, and signal transmission. This argument is in line with my aspiration to scientific metaphysics, and so I should demonstrate some support from science and the philosophy and methodologies of science.

I suggest that the contingent existential basis of these structures is that they I-obtain as and reduce to defeasibly as nonuniform, heterogeneous, bounded (and interacting) fields (§7.1 p249.)

In other words, I am not leapfrogging or contradicting contemporary physics and asserting that a causal structure mediates the non-local effects of entanglement. I am only asserting that any physicist can take either one or both of the entangled particles in an entangled system and treat them as an information source. They can be treated as apparently physically connected bounded regions of a nonuniform multidimensional physical quantum field. (Smilga, 2017; Lancaster and Blundell, 2014)

6.3.2 QFT and Scientific Realism

There are at least two basic problems with physics and Quantum Field Theory from the perspective of physicalism and scientific realism. One is that there are serious debates about the ontological status of the various quantum fields supporting standard model particle realisation. The other is that physico-mathematical operators are common in quantum physics, and they are often either identified or conflated with the entities that they are being used to model and/or track. This lends itself heavily to both instrumentalist interpretations, and to formalism driven ontological descent.

When physicists say gravity and electromagnetism are fields, they mean physical *I*-obtaining fields. The mathematical apparatus that represents them are also called fields, and they have mathematical properties. We must keep in mind, however, that physics is replete with physico-mathematical operators - like the operators of quantum mechanics. Field theories (plural) are taken to describe every point in spacetime permeated by a given physical field type: gravity, magnetic, electromagnetic, and so on:

> Every particle and every wave in the Universe is simply an excitation of a quantum field that is defined over all space and time. That remarkable assertion is at the heart of quantum field theory . . . Quantum fields are defined over space and time and so we need a proper description of spacetime, and so we will need to use Einstein's special theory of relativity which asserts that the speed c of light is the same in every inertial frame . . . even matter itself is an excitation of a quantum field and quantum fields become the fundamental objects which describe reality. (Lancaster and Blundell, 2014, 1-2 0.1-0.2)

Since spacetime is taken to be everywhere in special relativity, so is a (or the) quantum field. Moreover, gravity permeates all of spacetime, and to the gravity field is likewise co-extensive with spacetime in terms of its distribution. However, with respect to the quantum field as a basis for the existence of the structure of physicalist ontic structural realism - and more specifically FOSIR - there are a number of potential problems:

Pancomputationalism, Simulation Theory, and Digital Ontologies As has been mentioned at §3.4.4 p131 and §4 p137 (see further discussion at §7.4.2 p265), many serious and respected physicists and philosophers of physics take some version of pancomputationalism or digital ontology, or in some cases some version of mathematical ontology that is not statisticalist (like the physical-world-as-math ontology of Max Tegmark). The views are often interpreted as anti-physicalist, or at least non-physicalist.

Instrumentalism about QFT As I will discuss below, eminent philosophers of physics with instrumentalist and constructivist dispositions take it to be the case that quantum fields are constructs in theories used to calculate measurement outcome statistics only (See the comments of Michael Esfeld from private correspondence below).

Concrete and Abstract Algebras There are many interpretations and variations of different versions of algebras in QFT. They are taken to avail themselves of different ontological interpretations, or sometimes to make no ontological (let alone physical) interpretation available. (Kuhlmann, 2015, 5.1)

QFT Interpretation There are impediments to physical interpretation of the mathematics of quantum field theory.

So there are serious doubts about whether QFT can provide a basis for any kind of ontology, but at the very same time, it is little doubted by most quantum field theorists and physicists that quantum fields *I*-exist and that the mathematical models of how particles and quantum systems emerge in them frequently refer to actual physical excitations in fields. Some instrumentalist philosophers of physics, however, are not convinced by a scientific metaphysical approach of the kind I am endorsing and deploying:

> To my mind, one has to be absolutely clear about what one task the structures to be that are admitted as ontologically fundamental. That is the argument for working with concrete physical relations, such as distances. As regards QFT, a discussion of ontology makes only sense if one makes clear which formalism one uses to solve the measurement problem, i.e. what the dynamics is supposed to be and how it accounts for measurement outcomes. The fields used in QFT are operator valued fields, that is, instruments to calculate measurement outcome statistics. You cannot build an ontology on that. (Professor Michael Esfeld, Private Correspondence, December 02, 2017.)

At this point I make the following observations. I will do this in point form not to be overly formal, but to make my premises and suppositions as clear as possible:

1. I am not of an instrumentalist disposition, and neither is the CICS-FOSIR conception of information intrumentalist or constructivist (nor is it subjectivist, platonist, nominalist, or mathematicalist) and nor are fellow scientific metaphysical endorsers Ladyman and Ross, French, and Humphries: scientific metaphysics does not encompass instrumentalism.

2. Ladyman and Ross' ontological assertion "the world is the totality of nonredundant statistics" *does* in fact accommodate Esfeld's above comment about the limits of QFT for making and ontology. However, it does not have to be

governed by it: according to Ladyman and Ross' conception of a world of nonredundant statistics, the statistics are:

i. Physical (Ladyman and Ross have not abandoned physicalist ontic structural realism)
ii. What I have called I-obtaining: the statistics inhering in the physical stochasticity is theory, model, language, computation and mind independent.

3. I take it that what Esfeld is committed to is in fact ultimately what French has termed mathematical collapse, and comes under the head also of what I have called *formalism driven ontic descent*.

4. In the context of a scientific metaphysics, there is strong support for my physicalist I-ontic disposition about fields: that they are not just statistical constructs or formalisms based upon measures, but that they I-obtain physically as much as Michael Faraday took magnetic fields responsible for magnetic forces or attraction and repulsion to be physical and I-existent. This is because in the context of the history of field theories - at least since Michael Faraday's discovery and exploration of magnetic fields - physicists have considered fields to:

a. Have physical effects (Kuhlmann, 2010b)
b. Sustain physical entities (including particles and waves) (Lancaster and Blundell, 2014; Kuhlmann, 2010a; Smilga, 2017, 18, 3.1)
c. Not just be mathematical or constructs
d. Be I-existing entities in the world with I-obtaining physical structure, and not just to be constructs in theories and models in theories that do instrumentalist explanatory work.
e. Be capable of participating in causal interactions where the underling conception and/or theory of causality and causation is physicalist (including mechanistic and process-orientated theories)

To me, the immediately apparent issue with considering the quantum field to be the basis of a physicalist ontic structural realist ontology is not - as instrumentalist Esfeld would have it - that it's not suited to the purpose of furnishing an ontology by instrumentalist lights. I take this to be begging the question in favour of theory and model instrumentalism. I will avoid engaging with debates about scientific realism at this point due to scope limits, except to say that elsewhere I have argued that, commensurate with scientific metaphysical premises, something like a statistical re-expression of Ian Hacking's corroboration argument - which essentially argues that if Putnam's no miracles argument is to be taken seriously then according to inference to the best explanation an I-existing external physical reality is the best explanation for empirical data in science - is more successful than generally believed. More basically, the scientific metaphysical mandate requires that we give significant credence to scientific authority and the primacy of physics constraint (PPC). It is clear that this approach favours the scientific realist ontological disposition of most physics and physicists.

This can be supported by reference to the way in which the various mathematics of the field theories of the stand model particles and their properties are adduced using various manipulations of different mathematical representations of fields, but it can be more straightforwardly revealed in terms of the way in which quantum field theorists do, and expect to, ratify their models:

> The discovery of a Standard Model (SM)-like Higgs boson [1, 2] is a milestone in particle physics. Direct study of this boson will shed light on the mysteries surrounding the origin of the Higgs boson and the electroweak (EW) scale. Additionally, it will potentially provide insight into some of the many long standing experimental observations that remain unexplained (see, e.g., [3]) by the SM. In attempting to answer questions raised by the EW sector and these presently unexplained observations, a variety of new physics models have been proposed, with little clue which - if any - Nature actually picks . . . In this paper, we make use of the Standard Model effective field theory (SM EFT) as a bridge to connect models of new physics with experimental observables. (Henning et al., 2016)

In response to the assertion that some physicists take such things as pancomputationalism, digital ontology ("it from bit"), and simulation arguments seriously, I proffer that pancomputationalism is still naturalist and physcalist (it's physical natural phenomena that are themselves taken to be the computational elements), digital ontology is largely instrumentalist up-front (front loaded with instrumentalist premises about yes-no queries in theories), and in the case of the simulation theory there is a fair charge of a looming regress (What's running the simulator - another simulation? Is it simulations all the way down? Are the simulators not physical and physico-causal? If not, then given the bite of Rolph Landauer's claims about necessary physical representation of data in all real cases of digital and quantum computation: why eschew a physicalist basis for simulation and for the simulator?) The point is that asserting instrumentalism about QFT as a premise for doubting it as a basis for physical ontology is too quick, and largely circular, and it arguably fails the curbing premises of contingent scientific metaphysics, which are themselves contingent in the context of PPC.

Recall also that I have emphasised the defeasibility of scientific theories as an important and ineliminable element of a scientific metaphysical outlook. Defeasibility does not imply, nor does it entail, instrumentalism, any more than revisability of scientific theories entails the correctness of the extreme consequences of pessimistic meta-induction. Defeasibility of this kind saves me from commitment to immutable stipulations about ontology, but does not commit me to pessimistic meta-inductive inferences. I don't have to follow Esfeld into instrumentalism, as scientific metaphysics that emphasises the defeasibility of theories, methods, and modelling, avails me of a pessimism about theory fallibility with greater epistemic humility that does not require me to delete the I-ontology to accommodate the fact of partial representation and partial accuracy.

It certainly doesn't *necessarily* follow from the standing fact that there are many different mathematical and algebraic approaches to modelling in QFT that instrumentalism about QFT is true. I suspect that the truth is more closely approximated by Hacking's corroboration argument - the view that the reason for the efficacy of different theory-models is that they're all different views of some I-existing external referent to which science has access via noisy channels (along the lines described Ladyman et al., 2007.)

Reductionism

Reductionism causes some difficulties in philosophy and the philosophy of science, which is a result in significant part of the varieties of reductionism available. Sandra D. Mitchell minimises its role in comparison to the importance of emergence in complexity studies, but points out that it is impossible to remove explanatory and ontological reductionism from scientific practice and theorising (Mitchell, 2009.) Ladyman and Ross reject neo-scholastic reductionist overtures about microbangings, but retain Nagelian reduction (Ladyman et al., 2007, 196-7; [2].) Moreover, they do not reject Saunders' view that structure may reduce recursively and ontologically, so it is fair to adduce that they have not rejected reductionism about I-obtaining ontic structure.

According to Daniel Dennett's real patterns approach, which is designed to handle the relationship between patterns in (data, theory, explanation, and ontology) between physics and the special sciences (and between different special sciences), patterns in chemistry and biology can reduce - on information theoretic terms - to the information of the structure of underlying physical systems (Ladyman and Ross, 2013, 110.):

> Mere patterns—stable but nonredundant relationships in data—are distinguished from 'real' patterns by appeal to mathematical information theory. A pattern is redundant, and not an ultimately sound object of scientific generalization or naturalized ontology, if it is generated by a pattern of greater computational power (lower logical depth.) Then to be is to be a real pattern. Ladyman & Ross provide reconstructions of important concepts in philosophy of science such as causation and laws in terms of recurrent types of structural relations among real patterns. Most important claims that have been thought to be laws in the history of modern science describe such structural relations in mathematical terms that survive episodes of theory change in approximate form. Individual objects as used by

[2] For an overview of Nagel's intertheoretic reduction see this defense - Dizadji-Bahmani et al., 2010

> people for coordinating reference to a universe organized from specific parochial perspectives are real patterns of relatively high logical depth and thus do not feature in scientific generalizations. Furthermore, the important real patterns in science are not reducible to facts about the intrinsic properties or natures of individual objects. Ladyman & Ross defend a metaphysics that does not take individual things to be fundamental. (Ladyman and Ross, 2013)

Ladyman and Ross argue (effectively, I think) that Dennett's position in fact commits him to both a metaphysical thesis and to instrumentalism:

> However, in a now-classic paper 'Real Patterns' (RP; Dennett 1991a), he emerged from this [metaphysical] neutrality to frame his view of mind in the context of . . . a distinctive metaphysical thesis. According to RP, the utility of the intentional stance is a special case of the utility of scale-relative perspectives in general in science, and expresses a fact about the way in which reality is organized—that is to say, a metaphysical fact. (Ibid., 199-200)

However, in addition to being committed to Saunders' style of turtles [structures] all the way down reduction, it looks like being committed to scale relativity in the way that they are commits Ladyman and Ross to an instrumentalism of their own:

> Scale relativity of ontology is the more daring hypothesis that claims about what (really, mind-independently) exists should be relativized to (real, mind-independent) scales at which nature is measurable. (Ibid., 200)

Why call this instrumentalist too? Because it's the claim that what is essentially explanatory scale relativity is intrinsic to nature, but there is no reason to assume that structure in nature respects explanatory boundaries for its organisation, and so it looks like this reasonable take on scale relativity is an epistemic and theoretic imposition, tending toward formalism driven ontological descent. Nature presumably doesn't know or care about (various universalist idealisms and the anthropic cosmological principle notwithstanding) the difference between a structure deep in dynamical protein folding and one embedded in quark emergence by way of field excitation. That the new solutions required for the protein folding problem combine quantum physics and DNA science tend to bear this out. I accept scale relativity in the sense that I do in fact accept as part of a natural structural heirarchy that can be picked out arbitrarily from natural structures - but *arbitrarily*, and in *arbitrarily* many different ways. All such selections involve the identification of a CICS configuration which is a source.

What is going on is that epistemically tractable science requires the abstracting out (from both measured data and representations thereof) of a lot of low level structural I-obtaining information. It also requires a lot of interpolation by hypothetico-deductive posits to be confirmed as representative of real I-structure. I do not deny scale relativity. A scientific metaphysics must avoid scale invariant assertions - on contingent grounds (Humphreys, 2013, 55-6, 68.) However, if ontic I-reduction is a fact for a system, then patterns detectable at smaller scales can only be undetectable at larger scales due to noise and/or limitations in data acquisition (measurement), and can only be undetectable at smaller scales due to difficulties with isolating and associating all of the underlying microsystems and their microstructures due to limited resolution or else capacity of measurement apparatus.

Chemists and biologists don't practically attempt to reduce all organisms and molecular systems to underlying physics(Berenstain and Ladyman, 2012, 161.) Moreover, as with most special sciences - statistical and mathematical/computational patterns do most of the work. However, it doesn't logically follow that such don't so I-reduce. In the context of a scientific metaphysics, it is non-trivially relevant to debates about reductionism that the most recent advances in molecular bioscience - especially in research into protein folding and protein synthesis - have come to require quantum biology, which is a paradigm of (albeit statistically represented) physical physics-based reduction for the purposes of analysis, data gathering, and explanation.

Dennett's conception of real patterns as patterns in data requires a conception of data as something like what Landauer took them to be: representations. Dennett's patterns, however, can incorporate fictions, and this suggests (requires, in fact) addition of (semantic) information (representations bearing encoded information) from cognitive sources. According to Landauer, information-as-data representations must be physical, giving rise to a conception of data that is similar to Aristotelian *in re* or immanent realism about mathematical structures. The specific nature of the appeal to mathematical information theory in Dennett's real patterns is unclear for this reason, and for at least two other reasons. Firstly, there are several mathematical theories of information, and they are not unified.

Secondly, Shannon's quantitative theory of information offers a number of conceptions of information in statistical terms and with reference to what are arguably two kinds of entropy, and as Von Neumann indicated to Shannon - there is definitional difficulty with entropy (Cole, 1993; Tribus, 1963; See §2.4 p72) - and it is not clear which part of Shannon's theory would be appealed to as the basis of data. Ladyman and Ross (and Collier) seek to handle this by way of deferring to Collier's distinction between thermodynamic depth based upon entropy in evolution of natural systems for identifying salient (effectively real) elements of the ontology in bioscience, but deferring to logical depth for identifying structures that are real qua Dennett's real patterns classification:

> However, Shannon and Weaver provide only a theory of the capacities of channels for transmitting information in which the quantitative measure is relativized to initial uncertainty in the receiver about the source. To obtain an objective measure of informational

> content in the abstract (that is, non-thermodynamic) sense, one must appeal to facts about algorithmic compressibility as studied by computer science. The important measure for our purposes will be logical depth. This is a property of structural models of real patterns. It is a normalized quantitative index of the execution time required to generate the model of the real pattern in question 'by a near incompressible universal computer program, that is, one not itself computable as the output of a significantly more concise program' (Bennett 1990, 142).

Shannon does not speak of patterns (the word does not appear in his 1948 paper) but of such things as sequences of symbols and ensembles of continuous functions treated as messages and modelled using Markov analysis. Patterns or this kind - sequences of symbols - are certainly salient to algorithmic computational approaches to, and conceptions of, information. The CICS characterisation accommodates both.

There are a host of problems for real-pattern orientated OSR and ISR. They apply to the view of Ladyman and Ross as well as to that of Dennett and of Floridi. I suggest that until there is a clear conception of the nature of information and data, then there is little point talking about either Floridi's levels of abstraction or Bennett and Collier's logical depth except as in significant senses - arbitrary - rather than somehow ontologically prior. Ladyman and Ross think that scale relativity of ontology is intrinsic to the natural world, which is why real patterns seem to be hierarchical. As I have said above, I suspect that this is largely an (instrumentalist) epistemic and artefactual theory-driven imposition. I take it that real patterns do exist in nature because structure is CICS structure *or structures that reduce to CICS or in some cases supervene upon it* and that they can be graded and classified depending upon whether they can be described by patterns that are more computationally powerful (require less detailed work with reductively basic elements and variable for greater predictive power.) Any real-pattern-cum-CICS-structure hierarchy is arbitrarily selectable, and a different selection will yield overlapping but differently hierarchically arranged patterns. The kind of reduction that I am talking about when I say that structures may reduce to CICS structures includes that secured through encoding and decoding (either or both of natural and artefactual versions.)

I think that Ladyman and Ross's approach requires a much more rigorous definition of 'logical depth' than is on offer in OSR metaphysics to date (Ladyman et al., 2007, 218). The nature of data is just as problematic, as it is characterised differently and situated differently in the various ontological heirarchies offered by Dennett, Floridi, and Ladyman and Ross. Its nature is any one or more of relational, abstract, concrete, non-extended, I, non- I-and perspectival, depending on the version of OSR (Floridi, 2011c, 81-4; Dennett, 1991; Ladyman and Ross, 2013.) Data does not always seem to be the same thing. Sometimes it is physical and I-exists in nature, sometimes constructed, sometimes only the product of measurements, and sometimes a representation of one or more of these things (Landauer, 1991; Floridi, 2005b; Ladyman et al., 2007.) Thus my own view, which involves *in re* structure as selectable and encodable for representation based upon explanatory purpose and or other motivations, is close to Dennett's conception of real patterns as established by perspective pursuant to explanatory power as determined by computational power in terms of predictive-power to processing cost ratio.

Put in simple terms - what I have said in this part of this section is that levels of abstraction and scale relative scales are arguably innate and to be found in nature and natural systems in re, but that the arrangement and heirarchy taken to be somehow prior and intrinsic by Ladyman and Ross is imposed instrumentally, and per Dennett's argument could be imposed in innumerable other different ways because without the explanatory and epistemic requirements it's completely arbitrary. I think that it also follows from this that there are at least two kinds of reduction still prevalent in Dennett's schema - computational and infromational - and if my characterisation of the nature of information is correct, then the latter gives a stronger reductionism than either Ladyman and Ross or Dennett might be comfortable with. I intend to acknowledge these problems, but put them aside and focus on identifying and justifying an alternative basis for a physicalist reductionist NOSR: nonuniform natural-kind-heterogeneous physical fields (identical to or reducing to the configurations of quantum fields in both excitation and ground states). I suggest that the physicalist conception of NOSR is retained for structures that can be considered informational or information bearing: only physical causal structures - or structures that reduce to such - are informational. First of all, however, there has to be a reliable conception of the nature of structures as physical - or at least as not Platonic or abstract in a transcendent way.

6.4 How Does FOSIR Relate and Compare to (Other) Informational Structural Realisms

Donald Gillies has put forward a similar position to Ontic structural informational realism called Aristotelian informational realism in that it is explicitly anti-platonist (Gillies, 2010, 8 and Floridi, 2010c, 253-281 (Reply to Gillies).) However, Gillies argues for partial-constructivist reductive physicalist realism about both numbers *and* information, and has a mathematicalist conception of information such that it reduces to mathematics and symbols. Information is realised in the physical world, but is partly constructed by humans and partly exists in nature (Gillies, 2010, 8, 17.) I argue that although humans encode information into representations, human construction is not a necessary condition for the obtaining of information, including semantic information. I'm arguing that it's contingently apparent that the sufficient condition for the existence of information is the existence of physical spatiotemporal causal structure(s), including those not constructed by humans. I've also rejected subjectivism about information.

Gillies thinks that “mathematical realism might even be a special case of informational realism” (Gillies, 2010, 8. For similar views, see Tegmark, 2008, Bub, 2005, Bynum, 2014, Floridi, 2009a.) I favour informationism about mathematical entities based upon I-physical realism about information. It is realised by - and *encoded using* - spatiotemporal structures, and can be thus encoded into the physical structures of descriptions and mathematical constructs. Information itself is neither reducible to mathematical constructs (although there are certain ways in which it may be statistical if statistics and probabilities have I-obtaining aspects), though measures of information might be. Nor is it a universal (Barbour, 2015, 3,4,6-8.) Ontic structural informational realism has little else apart from anti-platonism in common with Gillies Aristotelian Informational realism. The other common feature is the idea that mathematical and ontic structure reduce to the same thing. However, in Gillies’ case this is an example of mathematical collapse for the ontology of information, which is what mathematicalist conceptions of information amount to. Gillies does not attempt to put information in the foundation of the ontology like Floridi and Tegmark.

Floridi seeks a kind of constructivist (he labels it contructionist) middle ground or alternative to accomodate objectivist and subjectivist intuitions. He’s proposed a conception of informational structural realism that is intended to be compatible with non-eliminative ontic structural realism and epistemic structural realism. However, it does not have the physicalist commitments of the I-Ontic structural informational realism that I am proposing (Floridi, 2008a.) I will reject that informational ontology on the basis that it inexplicably and unjustifiably/arbitrarily places data based upon relational entities (non-extended relational entities) at the reductive base of the ontology (and this is not just for semantic information.)

Floridi’s uses of the concepts of layers of abstraction that is important in computer science for systems modelling, computer architecture, simulation, and software modelling and design to help arbitrate the relationship between I-structure and models (Floridi, 2011c.) However, he does this without any commitment to the physicality of the I-world or its structure. Ladyman and Ross stop short at physical statisticalism and irreducible stochasticity as the bottom of I-structure. French stops at modal content. Tegmark and Gillies stop at mathematical structure as the I-structure (so the computation independent component of the my definition of I-may not apply.) Floridi stops at transcendental non-commitment to scientific realism about I-structure. I stop at what science currently says (with significant experimental support) is the universal heterogeneous nonuniform quantum field, defeasibly.

Floridi combines features of ontic and epistemic structural realism to produce what he calls informational structural realism, which he argues is compatible with both. A primary motivation for this is that Floridi, inspired by Dretske, has a naturalistic yet unavoidably subjectivist conception of semantic information (Floridi, 2008a, Floridi, 2011c.) Semantic information is defined as reducing to units of information that in turn are comprised of and reduce to (there is not really a better way of describing the relationship) well formed meaningful and truthful data. The data are truthful on the basis of a veridicality thesis according to which truthfulness is grounded in a defined purpose in a specific context at a level of abstraction that is not I-since "LoAs are always teleological and queries are formulated (results are offered) for a purpose, even if the purpose might be implicit" (Floridi, 2011c, 147, 155; Floridi, 2008c, 230.) They are well-formed according to some syntax. I think that Floridi's semantic conception pushes back on his ontological conception of information, forcing him into a kind of Peircian transcendentalist idealism (which is by no means a philosophically paucit view.)

Floridi is also interested in producing an informational epistemology and a logic of information as its foundation (Floridi, 2011c, 226, 344-5.) That logic is inspired by modal logics and is based on the replacement of doxastic and epistemic modal concepts (believing that and knowing that) with a modal informational conception of *being informed that* some state(s) of affairs obtain(s.) According to Floridi's theory, the nature of being informed involves prior knowledge of the state of a source and treatment of information as an abstract commodity that is true and somehow has truth as a necessary condition because it is required as the basis for knowledge. These premises are familiar from the work of Dretske (Dretske, 1981, 46-7, 65.)

I have removed the ontological and existential dependence of structure upon relations, regarding such as the first move towards formalism driven ontological descent. Floridi asserts that abstract relations are the reductive basis for the data that comprise the information units of semantic information (infons) are relational entities which are somehow identical to metaphysical non-uniformities (Floridi, 2011c, 85-7.) I have suggested that non-uniformities are not binary, and are not the basis of structure, but features of it.

Floridi's informational structural realism is not intended to directly unify ontic structural realism and mathematical structuralism. It is intended to reconcile ESR with OSR. Floridi does not claim, as does Gillies, that mathematical structure might be a special case of informational structure. However, he does say that data as nonuniformities embodying relations (of differences *de re* at minimum - Floridi, 2011c, 356) exist in all kinds of spaces. Mathematical spaces are included in this. There is no ontological existential dependency of physical data upon abstract data directly implied, but Floridi asserts that the bottom of the ontology of the entire world is informational in the very real sense that everything reduces to information:

> As far as we can tell, the ultimate nature of reality is informational, that is, it makes sense to adopt LoAs [levels of abstraction] that commit our theories to a view of reality as mind-independent and constituted by structural objects that are neither substantial nor material (they might well be, but we have no need to suppose them to be so) but informational" (Floridi, 2011c, 361.)

Floridi's ISR is non-eliminative about objects and emphasises the role of relations between objects posited at various modelling levels of abstraction as the existential basis of informational structure (Floridi, 2011c, 348-50.) This accommodates scale variance, yet it is a reflection of the difficulty of the debate about ontic structure in OSR as expressed by French that Floridi's data are concrete and yet purely relational:

> So, ontologically, data (as still unqualified concrete points of lack of uniformity) are purely relational entities. Of course, from a structural perspective they remain unknowable in themselves. (Floridi, 2011c, 356.)

Apparently it must be the way in which the data as relations are concrete that is unqualified. Floridi is attempting to reconcile ESR and OSR to some extent, but at this point I believe that Cao (Cao, 2003b, 57-60) and French's (French, 2006) view of I-structure is better supported by science. Floridi does not seem to be able to find a place in the ontic menu for concrete purely relational structure, and it is not clear what such would be in the case of the structure of physical phenomena and systems. His conception of how structure and relations are interdependent is arguably not clear or is ambiguous since, in addition to his assertion of the truth of ontic neutrality, his claim is that "cohering clusters of data as relational entities (differences *de re*) are the elementary relata we are looking for in our modified version of OSR . . . the structuralism in question here is based on relational entities (understood structurally) that are particular, not abstract and universal..." (Floridi, 2011c, 356.) If they are particular in the Armstrongian concrete or even immanent realist sense, then it is hard to see what makes them such, and how. I take it that Floridi is referring to some kind of Kantian particular: or monad-like existent. I have designed Ontic structural informational realism to dispense with such ontic glue and constructed abstract retinue as inflationary and anti-POP. I don't think that the admission of such Kantian particulars is excusable on the basis of epistemic access problems, since it's an informational structural realism with ontic realist commitments that is being presented.

So it is not clear whether Floridi's ISR unifies mathematical/formal and I-ontic structure, if only because it is not clear what his commitment to the concrete status of data means with respect to OSR. It does not look like ISR solves outstanding problems about the nature and content of structure. More importantly, it is not clear how mathematical relations and non-mathematical relations can both be concrete. Moreover, if mathematical relations as binary difference *de re* data are the basis for information, then it is not clear why such data can't be part of a computational process (Floridi, 2009a.) Yet Floridi is a-priori opposed to digital ontology. More significantly, if abstract mathematical relations are the basis for information just as concrete non-abstract relations as data are, it looks like the conflation of ontic and mathematical structure is unavoidable(Ladyman, 2014, S.E.P.5.)

6.5 Defeasible Field Ontic Structural Informational Realism: FOSIR

I defer to scientific metaphysical premises and identify the (irregular/nonuniform heterogeneous) quantum field as the basis of - in fact as identical to - the ontic structure of the I-world as the subject of scientific study according to Ontic structural informational realism. Ontic structural informational realism is/becomes FOSIR - Field Ontic Structural Informational Realism. Ladyman and Ross also place field theory - including its scientific realist commitments - at the bottom of the scientific metaphysical heirarchy, which does seem to not only imply, but require, both theory and ontology reduction:

> Ontology in this second sense—which is equivalent to naturalized metaphysics according to Ladyman and Ross (2007)— necessarily involves one in reflections on quantum theory, because no other currently mature part of science is reasonably intended to restrict all possible measurement values in the universe at all scales (pp 132) ... Lagrangians for different interactions is a major methodological pillar of QFT and its astonishingly accurate predictive success ... Taken more or less at face value, our best fundamental physics tells us that there are no little things. Consider again QFT, in which particles are excitation modes of fields, that themselves are assignments of operator-valued measures to regions of space-time. Particle number is frame dependent, and every generation of particles turns out to be a collection of effective degrees of freedom that approximate the structure of the underlying deeper field theory ... (Ladyman and Ross, 2013, 137.)

Ladyman and Ross retain entities like space time points as explanatory abstracta which reduce to relations:

> When it comes to space-time physics we have learned that the identity and individuality of space-time points is grounded in the metrical relations between them and not the other way around. The situation in other sciences is often similar. Biological individuality is relative to selection in the sense that to determine what biological individuals there are in some domain it is necessary to see what counts as an individual for the purposes of Price's equation (Ladyman and Ross, 2013, 138)

At first this sounds like a mathematisation: something like a mathematical structure - or Floridi's abstract data - as the basis of the I-ontology. However, instead it's a claim that relations are primitive, and prior to objects. The claim about determining biological individuality is interesting in the context of my own approach: some I-structure is picked out from total I-structure on the basis of representing structured mathematical constructs in the formal model.

According to my approach, I-relations are intrinsic to the I-structure of the phenomena being investigated. If the relations exist as abstract or direct representations in the formal theory, then they might be thought to be the basis of the structure *in the theory*. But relations in a theory are not identical to relations in the I-ontology: they are an encoded representation of the CICS information in the modeled phenomenon. You can delete the relation from the formal representation and yet that which it represents may still exist in the I-structure - which may have been modelled as a stochastic process or Shannon source. At the same time, the relations that were represented in the I-structure are not the basis of the I-structure: they are picked out from it based on formalisms designed for abstracting out structural information that is explanatory. It is the I-continuous structure that the relations and their picked out relata (features of the structure) are part of that is prior.

If according to QFT particles are excitation modes of fields, and fields defeasibly are I-structure, and if particles are regarded (as Ladyman and Ross would regard them) as relata - then it is evident that the field is contingently ontologically prior. A response to this is that it is jumping the gun to equate the quantum field even defeasibly with I-structure. However, my response is that French and Ladyman and Ross's scientific metaphysical aspiration leaves that as the only live option (French and Ladyman, 2003b, 47; Cao, 1997.) If it turns out that I-structure is not the quantum field at bottom, then relations will still be abstracted out of whatever the I-structure is contingently found to be objectively identical to. Defeasibly and contingently the content of ontic structure is classical fields and other phenomena to reducing quantum fields. Relata are features picked out of them because of explanatory and functional relevance (related to their properties), as are relations.

Ladyman and Ross emphasise the relevance of Dennett's conception of real patterns as one foil to thoroughgoing reductionism. Dennett's approach reveals part of the motivation for regarding that all of the non-redundant statistics as the totality of reality in conjunction with their commitment to irreducible stochasticity:

> The interest of the account is that it describes an order which is there whenever actions are done with intentions .... But how could the order be there, so visible amidst the noise, if it were not the direct outline of a concrete orderly process in the background? Well, it could be there thanks to the statistical effect of very many concrete minutiae producing, as if by a hidden hand, an approximation of the "ideal" order. (Dennett, 1991, 43),

QFT and therefore the quantum field and classical fields that reduce to it are not, however, just a formalism or set of abstracta, as is indicated in part by the predictive power of QFT:

> A structural realist view, at odds with both standard realism and standard instrumentalism, about the ontology of QFT seems

> completely naturalistically appropriate, and does not amount to regarding QFT as a bare formalism. (Ladyman and Ross, 2013, 135.)

I regard I-existing fields as being the basis of all structure - by way of being identical to it - including abstracted mind and theory dependent encoding of mathematical structures derived from $\geq n$ I-sources. There are just nonuniform (irregular) compositionally heterogeneous (defeasibly of different natural kinds) fields that are structure, and relations are a feature that can be picked out - or more specifically encoded - from them. What is a structure in the I-world? Just a nonuniform physical field or a complex of heterogeneous fields, with arbitrary boundaries (which boundaries may even be fuzzy or indeterminate.)

Ladyman and Ross defend their probabilist irreducible stochasticity based ontology as being the best expression of scientific metaphysics, but this does not seem to properly reconcile with their commitment to the I-obtaining of fields. Their fair charge is that denying stochastic irreducibility tut de suite is analytic, a-priori and dogmatic (Ibid., 140):

> Deutsch's dogmatic refusal to allow for the possibility of irreducible stochasticity is similarly conservative. We are by no means the first philosophers to argue that refusal to allow irreducible stochasticity in the fundamental laws of nature is a domesticating move based ultimately on residual analysis of some general metaphysical notions, especially causation. (Ladyman and Ross, 2013, 144.)

However, denying reducibility - or at least that statistical expressions are an effective encoding of information from nature on the basis of nomic regularities and experimental confirmation (see Long, 2014, Rickles, 2008b, and Ladyman and Ross, 2013) would also seem to be equally dogmatic, especially given that defeasibility should apply to both methodology as well as to ontology. There is a question about the kind of reducibility that is at issue here, however.

I have elsewhere referred to the problems associated with open questions about the nature of probabilities and how formal statistics is taken to refer to or encode information from the I-world. A brute yet correct way of stating this approach to I-ontology overall is that Dennett's real patterns are all ultimately defeasibly existentially dependent upon and reduce to I-obtaining physical fields. Using supervenience as an explanatory device (see Hüttemann and Papineau, 2005, 34; Pettit, 2009; Kim, 2005): defeasibly - if there were no quantum field there would be no real patterns of any kind - abstract or statistical or otherwise.

It's interesting that Ladyman and Ross allow that structures are comprised of structures. It is difficult to see how to characterise this except in terms of reductionism - especially given a scientific realism about I-structure (Ladyman et al., 2007.) They acknowledge the reductionist status of QFT, reject domestication of science by a-priori analytic edicts, and yet seem to all but prohibit reductionism on a similar basis:

> Quantum entanglement in particular and quantum physics in general, especially quantum field theory, show that there is no sense

> at all in which atoms or sub-atomic particles resemble little macroscopic things reduced drastically in size. In undomesticated physics, particles don't resemble any kind of entity that people had ever imagined prior to the twentieth century.1 3 This is a decisive consideration in favour of anti-reductionism: there is no convincing reason to believe that the micro-scale mechanistic structure that the reductionist treats as explanatory bedrock exists.(Ross et al., 2013, 143.)

Statistics seems to be as good a tool as any for domesticating science, if one makes it the arbitrary endpoint of investigation and metaphysics. In information theoretic terms what this seems to threaten is that there is no intrinsic semantic content to I-information - only statistical magnitudes and patterns. As French, Chakravartty, Psillos, and Cao have pointed out - albeit with various ontic commitments - the apparent absense of ontic content - the nature of the structured thing beyond it being structured - is an unsatisfying outcome for ontic structural realism (see §3.3 p90.)

Ladyman and Ross offer an argument from non-reductive practices in science, but this fact does not prove that I-reduction to concrete microsystems does not obtain in nature, and it seems to devalue the many reductive successes of science. Moreover, there is a straw man here with respect to the rejection of any grounding. The reductionist does not have to believe in a fixed ontic bottom or foundation: only that one set of physical structures and dynamics reduces to and is comprised of other structures and dynamics.

The prevalence, power (in terms of its ability to determine and/or adduce data where it is otherwise unavailable) and effectiveness - dominance in fact - of (specifically frequentist and non-subjectivist) statistical analyses in contemporary science is a fair basis for a stochastic structuralism:

> The importance of Peirce's interest in psychophysics was, as Hacking explains, that it encouraged him to reconceive of properties of frequencies not as second-order properties of judgments, which people strive to bring into correspondence with fixed underlying constants, but as basic properties of the external world that constitute its structure. Remarkably, Peirce recognized in this idea the basis for a new conception of scientific method, the method that now overwhelmingly dominates the everyday life of the scientific community across almost all disciplines, of exploiting the systematic patterns of variation in large data sets generated by known processes to minimize estimation error— that is, to tell noise apart from structure. Where randomization with respect to a dependent variable in a model of such data can be experimentally imposed or instrumented, regression can even be used to discover causal relationships (Angrist et al., 1 996; Angrist and Pischke, 2009)—on the Peircean understanding of causation indicated above. Such estimation is core activity in every science that relies on modeling

> quantitative data—including, in particular, quantum physics . . . the Peircean hypothesis we invoke to explain. . . the efficacy of statistical theory is the simplest one to which a realist should have recourse: the world is stochastically structured. (Ladyman and Ross, 2013, 145.)

However, Ladyman and Ross want to claim a very strong stochastic irreducibility in nature, which they take to extend to a thorough anti-reductionist outcome (in keeping with their arguments from scientific practice):

> It follows from the truth of general anti-reductionism that, however completely the generalizations of fundamental physics constrain all measurements taken at all scales of real patternhood, one cannot hope to explain all or most real patterns by showing that they are determined by these generalizations. Were this not true, we would indeed expect that many putative 'higher level' patterns would be reduced away—eliminated—and thus turn out to be ontologically redundant. Most of these non-redundant non-reducible patterns are also irreducibly statistical, in the sense that they are generated by stochastic processes. (Ladyman and Ross, 2013, 146.)

Reductionism - both theory reduction, conceptual reduction, explanatory reduction, and ontological reduction - is used frequently enough in successful science to make the claim of correctness of general (read as thoroughgoing) anti-reductionism a non-sequitur. It is probably not the case that 'higher level' patterns are ontologically redundant if they reduce, especially according to an ontic structural realist scientific realism. They may still be enlisted to provide defeasible adequate explanations or involve variables and parameters that are casually efficacious and explanatory. Moreover, ontic structural realism is by definition realist about structure, none of which is regarded as ontologically redundant even if it is reducible. This can all remain true even if natural I-structures are stochastic. Moreover, it looks like QFT supports the view that we should allow possible infinitely reducible field structures (Ladyman and Ross, 2013, 135.)

As Ladyman and Ross have noted, physics underdetermines metaphysics in the sense that there is not enough agreement even among scientific realists about what exactly is mind and language independently real and what is - say - a statistical representation thereof. There are further open questions from quantum mechanics and quantum field theory regarding which model is more correct (Ladyman and Ross, 2013, French, 2014.) However, if there is a characterisation of mind and language independent structure to be had in scientific metaphysics, then I think that eliminativism and nominalism about information in physics should therefore be off the table, and thus eliminativism about information in the hard and soft sciences in general.

6.6 Content of Structure

Ladyman and French are aware that Cao (understandably given their apparently ambiguous stance regarding the nature of relations for mathematical structures versus material structures) charges that they are Platonists about the structure of their OSR ontology, and correct the impression:

> Cao understands us as advocating 'the dissolution of physical entities into mathematical structures'. But, first of all, by 'dissolution' we mean metaphysical reconceptualisation. And secondly, as we tried to emphasise, to describe something using mathematics does not imply that it itself is mathematical – the structures are what they are and we describe them in mathematico-physical terms. Let us put it as clearly as we can: we are not mathematical Platonists with regard to structures. (French and Ladyman, 2003b, 75.)

Nor, as I went to pains to articulate at §1.4.1 p49, am I. I am claiming, in the face of non-reductionist physicalism of most NOSR, that the dissolution in question (formalism driven ontic descent where maths becomes all that is accessible, or else French's mathematical collapse, where it becomes the actual basis of the ontology [3]) maps to a reduction and complex encoding process involving ineliminable information channels realised as signal pathways which have continuous causal pathways as a necessary condition. Mathematical structures reduce to the same kind of informational structures as everything else that is informational. In this thesis I am claiming that the only real structures in the ontology are or reduce to I-obtaining physical spatiotemporal structures that reduce to quantum field regions (See $IS1$ at §4.6 p171.) This is a much stronger physicalist content claim - in terms of ontic commitment - than that made by Ladyman and Ross and French.

The contingent OSR I want to deploy involves a still stronger or more radical claim: structures do not reduce to either formal relations, nor some kind of I-obtaining mathematical (Platonistic) relations, and are not existentially dependent upon or grounded in/by them (See §3.3 p101.) One motivation for this move is that in this thesis information is realised at bottom by the configuration of spatiotemporal causal structures (bounded nonuniform regions of heterogeneous fields.)

I provided contingent and scientific metaphysical support for the quantum field as structure for Ontic structural informational realism in greater detail at §3.3 p90. At this point an introduction of the versatility and universal application of QFT in physics is salient:

> What is Quantum Field Theory Good For? The answer is: almost everything. As I have stressed above, for any relativistic system it is a necessity. But it is also a very useful tool in non-relativistic

[3] Thus the two are different

> systems with many particles. Quantum field theory has had a major impact in condensed matter, high energy physics, cosmology, quantum gravity and pure mathematics. It is literally the language in which the laws of Nature are written. (Tong, 2007, 4; See also Lancaster and Blundell, 2014, 1-2)

QFT involves formal representation, to be sure. However, its premise is scientific realism (Mathur, 2009b, 7-8.) If we regard the spacetime manifold M as I-obtaining, then it is the quantum field that we should regard - defeasibly - as its content and its reductive ontological basis. My brute abstracta-eliminating identity thesis is that nonuniform heterogeneous quantum field is identical to Ontic structural informational realism structure. My intention is to defeasibly pick ontic I-structure straight out of the menu of contingent (defeasible) ontic furniture discovered by physics - the nonuniform heterogeneous quantum field.

French and Ladyman's NOSR retains scientific realism about object-relata but regards them as all but irrelevant for scientific modelling and explanation compared to relations and thus structure. Ladyman and Ross have introduced the idea that if the structure in ontic structural realism does I-obtain, then it is derived from statistics that exist in the I-ontology as the content of the structure. They defer to Daniel Dennett's real patterns, more than to relations, as the basis for intrinsically statistical I-structure, about which they are scientific realists (French and Ladyman, 2003b, 42, 47; French, 2014; Ross et al., 2013.) The hallmark of Dennett's real patterns is that they are allegedly objectively not reducible, and Ladyman and Ross follow suit with irreducible stochasticity of natural structures. French has since moved to an innatist modalist ontic structural realism (French, 2014, 231; Refer to §2.3 p62)

Meanwhile, Ladyman and Ross develop a statistical NOSR according to which " the world is the totality of non-redundant statistics, not of things" where the statistics arise from Dennettian patterns because " Most of these non-redundant non-reducible patterns are also irreducibly statistical, in the sense that they are generated by stochastic processes" (French, 2014, Ladyman et al., 2007, Ladyman and Ross, 2013.) Michael Esfeld has suggested a middle ground based upon quantum mechanics and particularly the challenges presented by entanglement for scientific realism (Esfeld and Lam, 2008.) Esfeld deals with the problems of intrinsic properties by emphasising that in entanglement there are no properties of the individual entagled systems available - only properties of the whole entangled system (Esfeld and Lam, 2008.) He leverages a strong non-supervenience principle developed by Carol Cleland to retain relata but make the intrinsic properties of relata (entanglement related quantum systems in Esfeld's case) irrelevant to the obtaining of relations, but without requiring the elimination of relata from the I-ontology (Esfeld and Lam, 2008, 612-13.)

French's more recent version of NOSR regards that mathematical collapse of any kind is unacceptable, and he reintroduces causality as the differentiator between mathematical structure and what I have called I-structure. Causality is also a mainstay of the NOSR and the philosophy of information that I develop here.

I reject that structure is the limit of what we can be scientific realists about. I agree with French that mathematisation of the I-world is not an ontic scientific realist approach, but instead constitutes a specious conflation of patterns and relations in a formal model with that which is being modelled. There are indicators from the physico-mathematical tools of physics that this is true. Proofs of the renormalisation theorems in QFT involve cancellation of most terms that initially arise in them, going from ontologically inflationary to minimalist, which tends to confirm that it may well be the case that formal mathematical models encoded to represent physical reality are inherently ontologically inflationary (Zeidler and Service, 2009, XII, 131.)

I do not propose that I-ontic structure is somehow indicative of natural content, but that it does in fact defeasibly reduce to specific parts of that content in the sense that it is identical to it. I bite the bullet on the question of what it is that is causal and 'latched on to' by science, by saying that it simply defeasibly is whatever science suggests. I suggest that science suggests that structure is an I-obtaining element of the I-ontology by virtue of being (defeasibly) identical to bounded configurations of nonuniform heterogeneously constituted fields (classical reducing to quantum.)

If I-structure is somehow accessible - then that structure simply is the I-obtaining ontic content of the natural phenomena/systems under investigation and being represented. It's the opposite, ontologically speaking, of formalism driven ontological descent: the I-ontology supplants what were considered to be abstracta. According to Ontic structural informational realism I-structure is only abstract in the sense that it is abstracted from the total I-contents of the natural phenomena as a causally induced (multiple transduction reducible [4]) encoded selection of the total structure.

French attacks Max Tegmark's mathematical universe hypothesis as an example of mathematical collapse since according to MUH the mappings between mathematical structures in physics and symmetries mean that the underlying structure is identical to the mathematical structure *as* mathematical *only* (French, 2014, 195.) I am adopting an *almost* opposite ontological shift (but not quite): structures thought of as only abstract are in fact abstracted from, or abstracted *away* from, or abstracted/selected/picked out from the I-structure using a complex encoding process as discussed at §6.2.1 p212 above in relation to the black box encoder solution to the symbol grounding problem.

Deferring this representation-encoding problem and returning to the reversal of formalism driven ontological descent - the answer to the question "what is the structure that is latched onto in the I-world when the representation is encoded?" (even if this involves posits and constructive invention) is literally

[4] By 'multiply transduction reducible' I literally mean that all processes of extracting information from one set of I-sources and representing it in other structures requires - at bottom - conversion from one kind of energy to another. This includes all neurologically based intrinsically semantic physical processing of physically reducing information in the brain and all instrument based extraction of physical data *from* I-obtaining natural sources (this stands under instrumentalism also at minimum in the sense that the conversion of information in the instrument to the instrument user reduces to energy transduction as a significant ineliminable element - although energy conversion is not the whole of encoding.)

that it is a selection of the actual content or natural substance of the material world. The I-structure just is part of the content. So I favour something close to, but not identical with, what Steven French has called *in re* structural realism:

> Two forms of structuralism can then be introduced: 'ante rem' structuralism which takes structures to be abstract,freestanding entities which exist independently of the systems (which 'exemplify' them); and 'in re' structuralism, which denies that structures are free-standing - rather, systems are ontologically prior to structures and talk of 'the' structure is understood either as talk about any system structured in a certain way or talk about all systems structured that way (French, 2006, 175.)

According to Ontic structural informational realism, it's the immanent structure of the particular source - the region of the QFT field/vacuum (refer to §3.2.1 p85 for definitions) - that is not just the *basis* of the structure, but identical to it. The structure is not an Armstrong style of type - a universal. Although there is no in-principle reason why such a universal could not be invoked, it is not a necessary condition for the existence of the structure.

My claim is *not* that such things as energy, matter, plasma, entanglement, phenomena, dynamical systems, microsystem are just structure where structure is some abstract ontic additional furniture. The claim is bipartite and comprised of a weak and strong assertion, that the aforementioned assorted (scientific realist alleged) existents defeasibly I-obtain, and:

a. (Weak Claim:) Are intrinsically and ineliminably physically structured/structural.

b. (Strong Claim:) Have an intrinsic I-structure that may well be inseparable (apart from abstracting away from) from their causal and intrinsic properties.

What is abstracted *away* (hidden or excluded) [5] from the I-obtaining phenomena when their structures are encoded into representing structures is the natural kind heterogeneity, while what is retained is the nonuniformity. What proportion of the interactive causal propensities of a microsystem come from its configuration or spatiotemporal arrangement, what proportion from natural kind properties, and if properties reduce to information, what proportion of natural kind properties and interactive propensities reduce to configuration of structure only? I will stick with a contingent analysis that ascribes interactive causal propensities to both nonuniformity and heterogeneity of natural kind content, and I do not seek to attempt to characterise the latter in terms of the former. The work is defeasibly done by type identifying I-structure with features -or continuous subparts - of fields themselves.

In a sense then there is a inverse parallel/analog to what happens with digital, quantum, and analogue computers alike. Such computers have physical (in every sense of the term 'physical' that matters) microarchitectures

[5] As opposed to abstracted *out* from or selected from or picked out from (or isolated from)

that are designed to physically represent (implement, in fact) logical relations and operations. The situation here is converse and sometimes naturally occurring (but sometimes cognitively dependent): physically represented logico-mathematical rule-based structures are constructed to represent I-obtaining (or at least instrument-sustained and obtaining) structures. In Chapter §5 p175 I argued that the structures in both situations are intrinsically semantic (§5.4 p189.)

The I-substructure that gets encoded into the formal theory as a representation of some kind is selected and abstracted from the I-system(s)/source(s) either arbitrarily based upon the best detection, and/or based on the purpose of the representation. French notes that picking the correct structure seems arbitrary:

> Thus the structures of natural systems are, 'if anything', in re. But then what is it that privileges a particular structure as the structure of that system? (French, 2006, 176.)

French notes that Psillos complains that choosing the right structure as being determined by what saves the phenomena or gets some nomic constraint based relations right leads the OSR theorist to "take the *in re* option, and has to accept some non-structural element" like objects and (allegedly non-structurally reducible) properties. French's response is that:

> [T]he ontic structural realist ... should not accept that the system, composed of objects and relations, is ontically prior to the structure. Indeed, the central claim of OSR is that it is the structure that is both (ultimately) ontically prior and also concrete. (French, 2006, 176.)

I declare a pox on both structuralist houses: structure is not prior to phenomena and physical systems because it just is and reduces to the quantum field, but nor are objects and relations ontologically prior: they too reduce to the quantum field (defeasibly.) The ready complaint is that the quantum field itself is ontologically mysterious. However, my response is that introducing an even more mysterious abstract ontic glue or substratum and trying to make that the basis of material ontology is worse - as at the very least then one has two mysterious pieces of ontic furniture and the need to explain how they are related. Not to mention that the quantum field is at least in-principle and to a significant extent contingently accessible to measurement and verification (Bub, 2005, 542-3.) Making the basis of the ontology a mathematical formalism in accordance with what I have termed *ontological descent* presents those two problems and additionally a serious question of a-prioricity: models that pre-exist complex systems being modelled are statistically unlikely to be common (and that assertion *is* based upon classical information source and channel theory.) There is just the physical structure of the natural information sources.

When a formal theory represents part of the I-structure, then what is represented is thus a selected *part* of the defeasible bottom of the ontology. The rest is whatever it is intrinsic to and may in fact contribute to the causal and intrinsic properties of the system/phenomena as a physical source set. Thus according to Ontic structural informational realism properties probably reduce to I-obtaining CICS information.

Whither Causal Efficacy?

The discussion above at §6.3.1 p214 presents an argument that causal pathways do not have to be continuous qua contiguity, especially with reference to the implications of Bell's inequalities and the accompanying experiments (see further discussion at §7.3 p252). However, that does not address the issue of the nature of causation itself. Chakravarty charges that structure alone cannot provide enough ontic basis for explaining change and properties in natural systems/phenomena (Chakravartty, 2004.) (Psillos, 2001) has suggested that NOSR does not have the means to explain the causal efficacy of objects in systems. Ladyman has retained objects in the ontology for similar reasons - as necessary to the explanation of casual properties and sustaining of properties. However, I agree with French, who defends scientific realist structuralism as able to answer all of these alleged explanatory shortfalls:

> Indeed, she can respond to Chakravartty's concerns by insisting that the explanatory buck stops at a point down the chain before we reach objects. That is, she can insist that this active principle lies with the relations and properties themselves, and it is these which carry the clout. (French, 2006, 180-1; For a more recent position see French, 2014, 210.)

Ontic structural informational realism places causal efficacy directly in the I-structure as a structure that is intrinsic to the nature/substance/content of the natural system/phenomena. Carving the ontology between structure and substance is only necessary for formal modelling where mathematical abstracta are demonstrably useful for manipulating Dennettian real patterns (that I suggest do reduce despite their original characterisation: refer to the arguments in and at the end of §6.3.2 p221) Carving the I-ontology between structure and substance is unnecessary and redundant except as part of the process of abstracting part of the structure away (isolating or picking out) from the entire structure of the system pursuant to isolating the causal explanation for the behaviour and properties of the system, and for the purposes of informing (by CICS based encoding) the formal representing structures. (These latter also all necessarily - naturally necessarily - reduce to CICS.) You can't have a 40 kilometre ball of Uranium 352 without an explosion, and you cannot have a representation without causally-induced (causal signals and emissions in causal signal pathways) physical structures to sustain it and upon which it existentially depends somewhere.

Ontic structural informational realism accounts for Psillos' concerns about causality on a similar basis to that which is suggested by French also:

> However, OSR does not advocate the analysis of all macroscopic causal processes in a structuralist fashion . . . [T]he **OSR account piggybacks on the physicalist's reduction of such processes in terms of ultimately quantum processes and then insists that the latter have to be understood in structuralist terms**. Imagine, for example, two particles of the same charge approaching one another and being mutually repelled. The OSR would take the currently accepted theoretical description of that process **whether in terms of field-theoretic interactions** or the exchange of force particles or whatever and would simply insist that rather than thinking of this description in terms of causally interacting physical objects, we give an appropriately structural description involving causal relationships. (French, 2006, 181.) (My highlighting.)

According to Ontic structural informational realism I-structure (defeasibly) reduces to exactly what is suggested here - fields embodying field interactions. Causality and therefore causal inducement of configuration reduce to the transmission of structure-altering energy through fields, where the fields are non-uniform in structure and heterogeneous in natural kind composition (There is a precedent for this in at least Fair, 1979.)

There are no microbangings: more like continuous micro-conveyance or micro-transmission by proximity, overlap, and adjoinment, except in the case of quantum entanglement and nonlocal effects or action at a distance, where all I can do is posit that the quantum field may contingently turn out to support strange signal transmission mechanisms which are still causal due to their nomic nature (According to Stephen Hawking, this may even allow signal transmission across event horizons in black holes (Hawking, 2014; See also Clifton, 2002, 151-3.) The structure that I-intrinsically inheres in natural systems thus is not imposed Platonically upon the existing system(s) total structure(s.) In accordance with the ancient conflict between the Platonic and Aristotelian metaphysics - the I-structure is abstracted out (picked out) from the total natural system structure (or has the total natural system structure abstracted *away* from it.)

French recounts the usual kind of discussion about causal powers and their relationship with causal properties:

> This raises further issues, to do with the relationship between properties and their causal powers or capacities, whether different properties can have or bestow the same power, whether the same property can bestow different powers on its instances, and so forth. Even metaphysicians admit that the connection between properties and their powers is not fully understood. One option is to insist that a causal power is a further property over and above the property that has or bestows it, but that introduces obvious complications and the possibility of regress; if this option is rejected, however, it is not clear

> what the relationship is. I don't think the structuralist should have to sort these issues out and there certainly appears to be nothing here that could not be appropriate (French, 2006, 184.)

Why talk about causal powers at all? They are not necessary any more than objects, and only breach POP. It's arguably due to another example of baroque definitional and descriptive formal theory and representation language and descriptive terms imposing themselves upon the I-ontology unnecessarily. Just because we feel the need to describe something in an abstractive and really largely metaphorically laden manner by talking about causal powers does not mean that there are actual casual powers I-obtaining in the natural system or phenomena. The system or phenomena just has a certain structure constituted a certain way and will interact with other structures on a certain basis empirically and contingently (and perhaps defeasibly even at the level of the I-structure.) I develop this fully below at §3.3.1 p111.

According to the approach of Ontic structural informational realism (which is non-eliminative about objects and properties since these are just labels for features of or subsets of structures) one can and should dispense with talk of powers just as one dispenses with talk of bundles. Without bruising contingency or inflating ontology, I will say that a feature is a possibly specifically functional (though possibly not) nonuniform *remarkable* causal CICS substructure. Remarkable simply means that the pattern or configuration of the substructure would stand out to a god-eye observer as significantly different to the rest of the structure, or is mathematically anomalous - would give markedly different mathematical representations - to the rest of the source in which it is embedded. A structure is casually efficacious in a certain way contingently because of its field content and the embedded context in terms of other sources that are proximate and present. Natural kind tokens (physical structured sources) have mutually recognised propensities w.r.t to each other that have been discovered contingently by empirical means and that are ascribable to physical nomic constraints or natural laws. That's all that's required. Whatever natural kind field reducing structure S^A naturally necessarily does empirically and contingently when it interacts with or even overlaps with natural kind field-reducing structure S^B is what natural kind structures like S^A can be expected to do - with significant statistical confidence - in similar settings. Further explanation requires picking out further microstructural features that seem to be intimately involved in the casual interaction.

A formal representing structure for modelling and explanation can be retained and reused - or even a-priori devised - as an apt fit for such structures in such systems. However, when the explanation is sought for the behaviour of the system, that it has such and such a mathematical structure is a faux explanation - or at least only an abstractive one: such a formal representing structure only represents part of the real physical I-explanation from causal pathways and nomic constraints. It can stand as an interim explanation that's epistemically efficacious in the same way as saying system A behaves like system B because they both have structure C or have structure that maps to a representing pattern P or model M. This explanation by comparison is not a full causal explanation of the causal properties of the system: that explanation will have to include the I-structure and its intrinsic relation to the substance of the rest of the structure of the system and how the properties and causal influences of the system are associated with the identified abstracted-away structure.

Eliminating Relations

Where I radically depart from French and almost all other OSR structural realists (with the possible exception of Ladyman and Ross in their more recent statistically orientated work) is that I dispense with relations also as primitive. I consider them,including property based relations, instead to be like spacetime points. Relations based upon physical properties - such as relative mass and relative velocity - may very well pick out or correspond to I-obtaining differentiae, but these can be described by reference to data or structure. There is no need to additionally reify any abstract entity called a relation, nor to assume that relative mass or relative velocities of two systems are the basis of their structure. Relative mass and relative velocity could be described as emergent from the entire system, for example. They might thus be real, but it is a leap to say they are the foundation of the quantum-field reducing system. After all, with a scientific defeasible contingent metaphysics the question arises: what non-formal relation I-exists between nonlocal entangled systems apart from a nomic empirically established regularity/prediction? Information theory demands that a signal has passed between the entangled quantum systems, but none has been found, and then there is the more pressing problem of apparent instantaneous transmission. Relations were already problematic:

> What we are faced with is a choice between particular relations or kinds of relations having, as features, causal aspects particular to those relations or kinds and some form of underlying causal activity which imbues the relevant relations with causal power. (French, 2006, 184.)

This choice is only necessary if relations are required as a foundation of structure in OSR. I am asserting that scientific contingency not only allows - but suggests - that relations are simply not required as a *basis* of structure, even if they are intrinsic to it. A justifiable description is that they are *emergent* in the structure (quantum field according to FOSIR) like everything else. The way I approach this is that there are infinite ways in which all features of a structure can be related. I am avoiding referring to points in a structure because these are generally conceived of mathematically, and because I think that structures are comprised of structural features - which are themselves subsystems and thus CICS sub-sources - and features are extended concrete parts of I-contingently defeasibly reducing structures. Features still don't have to be objects either, since they can be arbitrarily bounded and inhere in structures, and they can be picked out by identifying relations. Relations are themselves a feature that can be picked out from I-structure using formal representations or picked out or abstracted out from it on the basis of identifying first other features of the structures. I think that one can have I-structure *without* existential dependency upon relations even apart from an Ontic structural informational realism where I-structure is identical (defeasibly) to the quantum field, but I am deploying this identity theory anyway, and so the most I have to concede is that relations may be intrinsic to I-structure. I can concede this is ineliminably the case without conceding that they must be the ontological basis upon which structure existentially depends.

I suggest that the impression of the primacy of relations (Floridi, 2011c, 356) comes from the same origin as mathematical ontic descent and mathematical collapse (French, 2014, 193): we can speak of and describe relations in formal theories when referring to I-systems, but it doesn't follow that I-structure of I-dynamical systems and their associated stochastic processes would fall apart without them. It seems like - since relations appear to be able to stand apart from the I-structure - then structure cannot exist without the relations. I think it true that I-material relations are ineliminably intrinsic to I-structure, but it does not follow that the latter existentially depends upon the former as ontologically primary. Mutually perhaps, but I reject this also. I take relations to be like points: mathematical projections into the space of the structure based on the selection of features. It is possible that I-structure (based on fields for example) might reduce infinitely. However, if it doesn't and there is not really infinite structure(s) in an I-system, then there are still infinite relations. Apply the triangular argument for demonstrating and infinity of points on a line to see this (Galileo's paradox.) Given two features of a structure (an irregularity and a sub-structure) one can pick a point on one structure and map infinite lines to a line or curve of the other feature/sub-structure. Each one of these is a relation. However, given a structure, there was no necessary existential a-prioricity of relations. There may be a-prioricity of relations from the I-structure in the formal theory such that the structure of the representations in the theory depend upon the specification of the relations. I think that is frequently true. However, allowing that progression and existential dependence hierarchy to be inferred/descended back into the I-structure is simply a mistake.

Approaches that deny that either relata or relations (mathematical or otherwise existing) are the ontic basis of structure have been regarded - directly or by implication - as all but nonsensical by some theorists (Ladyman and Ross, 2013, 138; Floridi, 2011c; Chakravartty, 2004, 152-3; Cao, 2003b, 58.) However, the nature of structure is a curiously vexing issue in ESR and OSR:

> Poincare [6] is quiet on the subject of what structures are, and Worrall inherits this ambiguity ... What does it mean to say that mathematical equations are indicative of structure? It is insufficient for a realist simply to point to the equations of theories and claim that they in some sense describe reality, for constructive empiricists, instrumentalists, logical positivists and idealists agree with

[6]Poincare provided early inspiration for ESR based upon elimination of objects Chakravartty, 2004, 154

this much. (Chakravartty, 2004, 154)

More trouble arises, as I have already mentioned, with the conflation of the nature of mathematically established relations in the formal theory and its constructs and the nature of relations in the I-ontology. I suggest that the tendency to impose the relations of the formalism onto the I-obtaining structures being represented in the formal theory on a scientific realist or at least instrumentalist basis (which I have termed *formalism driven ontological descent*) seems correct partly because relations are simply features of the pre-existing continuous non-uniform structure(s) that already I-exist. According to CICS based Ontic structural informational realism (ontic structural informational realism) - relations in the theory are either 1. select information encoded from the I-ontology by various means or 2. representing structures that are encoded from the first kind of structures and other sources on a secondary basis and that participate in computation and modelling as artefacts of the model only

6.7 Ergodic Stochasticity Entails I-Structure

Assuming structure in the I-world is somehow ontically mathematical is unsatisfying and confused. Trying to abstract structure out from the I-natural phenomena is misguided if it involves the assumption that symbolic and/or Platonic mathematics is the ontic basis of the structure of the natural phenomena, and/or if Platonic mathematical structures are somehow identical with or of the same type as token structures in the I-system (Cao, 2003b, 63).

French and Ladyman have rebutted Cao's ascription of their approach as mathematical Platonism about I-structure, rejecting his assertion of an identity thesis. Cao understands ontic descent as operating in the opposite direction: the I-structure is ascended into the mathematical formalism such that it is identical to it rather than additional to it. I suggest that what is 'left over' is nothing other than more/further natural I-obtaining nonuniform heterogeneous field structure that has not been captured by the instrument and computation based theory and model encoding process. The interpretation of a mathematical structure can be abstract in the sense that one can demonstrate the turning of the handle of the mathematical machinery and use it to produce patterns that may be apt for representing features of the world or otherwise features of more mathematical patterns.

Cao's assertions are upheld by what Ladyman and Ross later enlist to adduce that the world is the totality of nonredundant statistics: stochasticity. Combined with classical information theory, the supporting argument runs as follows. If the mathematical representation and formal model is statistical - which is increasingly the case in the sciences - then a complex ergodic stochastic system will adopt certain states - and certain patterns of states - over time based upon nomic constraints. These constraints cannot come from within the formal model. They can only be captured by it. Physically nomically constrained frequentist data of stochastic source state I-natural processes are the best explanation for the source of formal statistical distributions. There is simply nothing in any Platonic mathematics that can drive these: no structure, causality, or dynamics. The I-external physical structured system is entailed to a greater degree by a statistical model the more complex the ergodicity becomes (the greater the variety of finite sequences of source/system states can represent the overall system behaviour in a predictive mode.)

In empirical theories, however, there have to be what Cao calls 'inputs' (Cao, 2003b, 57-59.) Additionally, French discusses the problem of how the I-content of some system or phenomenon is related to its structure, concluding that:

> [W]e might insist, crudely, that physical structure is concrete in that it can be related—via partial isomorphisms in the partial structures framework, say—to the (physical) 'phenomena'. This is how 'physical content' enters our theories and allows them to be (at least partially) interpreted . . . But of course, this content must itself be understood as fundamentally non-mathematical. One way of securing this would be to argue that there are mind-independent modal relations between phenomena (both possible and actual), where these relations are not supervenient on the properties of unobservable objects and the external relations between them; rather this structure is ontologically basic . . . This in itself renders structural realism distinct not only from standard realism but also from constructive empiricism. However, this option is not open if one is an eliminativist about phenomena, in so far as the phenomena has to do with, or is composed of, 'everyday' objects, such as tables, for example. From such a perspective, there is nothing to such objects that cannot be cashed out in structural terms, and so there is nothing intrinsically concrete about the phenomena and our problem returns. (French, 2014, 198-99)

I think this is evidently only a problem if phenomena are objects, but I allow them (dynamical systems, natural systems, stochastic processes) to be information sources per the classical theory of information. according to Ontic structural informational realism information sources are or reduce to heterogeneous nonuniform bounded regions of the quantum field. There is no mathematical collapse, but the I-ontology itself eliminates the need for certain kinds of abstracta.

An initial objection will arise from the mandate of the NOSR project:

> By way of consequence, however, if we give up Worrall's distinction between structure and nature, the argument for a metaphysics of relations can as such not say anything in defence of scientific realism against the challenge posed by the 'argument from pessimistic induction' (Esfeld and Lam, 2008, 613)

I sidestep this outcome by denying the primacy of relations, and by deferring defeasibility in NOSR as recommended by the kind of scientific metaphysics.

This preserves the ability of NOSR to avoid worries about such things as phlogiston, caloric and the ether (see the discussion about the quantum field and spacetime manifold M below at 3.2) being part of theories that have been superseded, whilst some of the mathematics derived on the basis of earlier wrong assumptions remains correct when applied to new referents. This is simply more indication that structure is the intrinsic relevant part of whatever I-exists that is being modelled. According to this view, a radical change in the content or nature of the underlying phenomena or microsystems - perhaps based upon the evolution of those microsystems - would change the structure as well (Ladyman and Ross, 2013, 144; Hacking, 1990.)

French and Ladyman initially assert non-committal ambivalence to the content of I-ontic structure, which they later revise to various different commitments including I-statistics (presumably meaning probabilities and stochasticity in nature) and inherent modal natures:

> Of course, what the structure is, remains an open question: a Kantian will have one answer, a phenomenologist another. Neither will appeal to a structural realist who wants to save a sense of objectivity involving significant mind-independence, unless their accounts can be appropriately detached in the manner we have indicated... (French and Ladyman, 2003b, 45)

However, I want to *embrace* a different but related identity thesis to that between mathematical and ontic physical structure that Cao attributes to French and Ladyman: the I-structure is a selection of the total region of the quantum field comprising a given system/source. The content is given defeasibly and contingently by QFT. It does not seem to be the case that one can say a field is *only* structure.

Real information, then, is - or else reduces to - the causally induced configuration of I-structures: classical fields and the quantum field. It may supervene upon such in terms of limited causal and epistemic access to the underlying I-fields, but I do not see the point of introducing any non-epistemically based supervenience principle. I do not deny that there are reasons to regard abstract structures and certain abstract relations as real, but I do deny that such abstract structures and relations realise real information unless they are specifically an encoded *abstraction from* real physical structures.

6.8 Conclusion

In this chapter I moved to situate my previous work in relation to the work of other philosophers of information and especially informational structural realists. I have further supported (§6.3 p213) my argument that instead of regarding that the content of the structure of Ontic structural informational realism is unknowable in principle, it is defeasibly identical to nonuniform regions of the quantum field and vacuum. This effective identity thesis about ontic structure provides a foil to both French's mathematical collapse and to the problem of distinguishing where formal representation ends and *I* ontology begins. It avails me of a way in which to defeasibly ground the realisation of information as causally induced configuration of structure in the ontology identified by QFT.

I then introduced the idea of a general conception of fields qua QFT as a basis for an ontic structural *informational* realism, and linked this with existing conceptions of structure per variants of NOSR.

I discussed Floridi's ISR, and especially its ontological reductive basis: binary nonuniformities regarded as data, and cohering clusters of data. I rejected Floridi's analysis on the basis that it is a-priorist, not rooted properly in scientific metaphysics, and conflates concepts of difference *de re* and nonuniformity *de re*, resulting in an a-priori binary discretisation of ontology that approximates the kind of digital ontology that Floridi has rejected. I have argued that instead of clusters of cohering data, the bottom of an information NOSR ontology should be taken to be sets of causally linked CICS sources.

I have rejected Ladyman and Ross's allegedly contingent tenet that the universe is the totality of nonredundant statistics on the basis with interpretational problems with the conception of statistics, and I have ascribed to it the status - or at least convergence upon the status - of what French calls mathematical collapse for similar reasons. I've also challenged their idea of irreducible stochasticity on the basis that it seems to be at odds with their allowances for Saunders' turtles (structure) all the way down reduction of *I*-structure per defeasible scientific metaphysics, and on the basis that a declaration of irreducible stochasticity seems at odds with uncertainty about exactly how it is that natural phenomena are innately statistical (this is brought out by the fact that French, for example, has a different analysis based on modal premises.) I've rejected French's modalist interpretation of the statistical mechanics associated with QM, and his idea that the possible representations that are implied by the sets of possible representations in models in QFT and QM for such things as particle modeling should be regarded as real. I have ascribed to this thesis of French's my conception of formalism driven ontological descent.

The idea is to move towards the fully developed ontic structural realism I need for a metaphysics of information as constrained by scientific metaphysics. I'll argue that the most appropriate OSR is most contingently coherent from an information theoretic perspective - is non-eliminative physicalist, causal structural realism (causal because the structure is causal.) It differs in various ways from the kind of reductionist physicalism that Ladyman and French, and Ross, endorse. However, there are also many similarities. Like French and Ladyman, I am averse to constructive conceptions of structure as the *I*-obtaining structure of the universe (French and Ladyman, 2003b, 73.)

Chapter 7

An Informational Statement of Physicalism

7.1 Introduction

My main objective is to argue for the *I* existence of something that constitutes the basis of what most scientists refer to as information, whilst avoiding platonism, nominalism, and formalism-driven ontological descent. In this chapter I further consolidate the identity thesis in the context of a discussion about physicalist ontic structural realism. I then move to use the FOSIR source ontology thus far developed to develop a statement of physicalism. This is reasonably ambitious, and my objective is to rely upon the work done in the thesis so far and avoid circularity.

I start by establishing the concept of informational and physical ontological closure at §7.3 p252. The idea is to establish by thought experiment the premise and hypothesis that physical structure and information are inseparable, which should follow from the field ontology structure, to ontic structure, identity thesis. The next step is to deal with issues about causal continuity, and to provide a brief argument for dealing with causal continuity in the important case of apparent instantaneous signalling over large distances due to spooky action at a distance. I have mentioned this severally in the previous chapters, especially at the first few paragraphs of §2.4 p72, and so in this chapter my treatment will be brief. Since this is the last chapter, I include some anticipated problems and challenges to various arguments presented herein, but I address issues mostly at the metametaphysical and metaphilosophical level, rather than continuing closer engagement with field ontology and the FOSIR source ontology foundations in QFT and the indispensability of (I-obtaining) information argument.

7.2 Situating Physical Structure Vs Formal Structure

I've no space for the debate between scientific realists and anti-realists, and I have chosen the NOSR alternative (with adjustments) anyway (Cao, 2003b; Cao, 1997; Cao, 2003c; Cao, 2010, 204.) To gain some context, French and Ladyman do not think that the real structures of mathematics are the same thing as the real structures of the physical world regarded as the ultimate object of study of physicists:

> Cao persists in lumbering us with two seemingly contradictory identifications that we thought we had rejected . . . The first concerns the identification between physical structures and mathematical ones, which Cao then takes to imply that the ontic structural realist must be a Platonist. (French and Ladyman, 2003b, 75.)

I suggest that Cao's alleged misinterpretation (which in fact does point to something like what French later refers to under the rubric of mathematical collapse) points to the right view for the metaphysics of information: a more traditional physicalist and scientific realist view (Cao, 2010, 202-6.) Neither French nor Ladyman and Ross commit to thoroughgoing physicalism in this way, presumably due to metaphysical and definitional difficulties. However, as discussed in the previous chapter, they each resort to a non-reductive physicalism, but neither allows physical structure to belong in the I ontology in anything but either statistical (Ladyman and Ross) or modal (French) terms. Thus, unlike Cao, who bites the bullet due to induction from the efficacy of physics posits (at minimum), they both end up committing to what seem to be two different versions of what I have called *formalism driven ontological descent* (§3.2.2 p87.)

French and Ladyman's unifying formulation of OSR distinguishes mathematical structure from physical structure, albeit with scare quotes on 'physical':

> Now, we did say that the distinction between the mathematical and the physical may become blurred, particularly if the mark of the latter has to do with 'substance' or individual objects or the like. Nevertheless, blurring does not imply identity. The mathematical can be trivially distinguished from the physical in that there is more of it; there is more mathematics than we know what to (physically) do with, which is what Redhead expressed with his notion of 'surplus structure'. What makes a structure 'physical'? Well, crudely, that it can be related – via partial isomorphisms in our framework – to the (physical) 'phenomena'. This is how 'physical content' enters. Less trivially, the mathematical can be distinguished from the physical in that the latter is also causal (French and Ladyman, 2003b, 75.)

This assertion is multiply supported - including by the mass cancellation of terms in renormalisation in QFT (Zeidler and Service, 2009, XII, 131.) According to French and Ladyman there is no such thing as an intrinsically physical structure - only structures that are somehow abstract but pick out parts of and/or are related to the physical system by something like a partial bijective isomorphism. It's not an isomorphism (invertible bijective mapping) between mathematical topological spaces, but a somehow a mapping between a structure in a mathematical space and the physical (see French, 2014, 195.) The 'somehow' seems to be that features or objects of some kind stand as relata in the phenomena which are mappable to structures in the formal representation. I analyse this somehow in terms of physically and causally reducing encoding of partial structure in the I-obtaining system as a source using other structures as destinations (See also Ladyman et al., 2007, 208 and Rickles, 2008b.) The surplus (formal) structure is presumably not physical, which is the reason that French and Ladyman give for Cao's call for an explanation. However, Cao seems to be concerned with what looks like French's conception of mathematical collapse for all of the structure.

Redhead and French and Ladyman leave space for platonism about informational (in explanatory terms) entities, but also other possibilities like immanent realism or fictionalism. Ontic structural informational realism is an immanent (or in re) realist solution according to which all real information (and pseudo-information is not information per §2.3.1 p68 and §5.6 p199) is realised non-platonically somehow. The 'somehow' in Ontic structural informational realism is that information reduces to the causally induced configuration of physical structures or structures that reduce to (or in some non-platonic cases, supervene upon) such structures. The approach allows that the surplus mathematical structures are (only) constructed artificial symbols (discretised atomic lexical and diagrammatic structures with rule based semantic content designated by cognition, reference, and epistemic content) or representational artefacts (diagrams, graphs) which encode, or facilitate the encoding of, heterogeneously constituted partial representations of information in or (abstracted) from natural phenomena and systems. There is no need to move from such structures and their semantic information content, which still cannot obtain apart from CICS and are semantic on the terms defined in chapter 5 (instrinsically via causal pathways including those involving complex heterogeneous structures such as causally induced neural correlates of mental content [1]) to the reification of platonic information. To do so is an ontological and logical non sequitur.

Ladyman and Ross later deny that physicalism is entailed by fundamental physics, which they take to be a *mathematical* enterprise and to ontologically privilege mathematical and non-physical structure:

> To anticipate, fundamental physics for us denotes a set of mathematically specified structures without self-individuating objects, where any measurement taken anywhere in the universe is in part measurement of these structures. The elements of fundamental physics are not basic proper parts of all, or indeed of any, objects...The

[1] and recall that I regard the information processed in cognitive requires to be itself physical: only physical or physically reducing information is real/exists

> primacy of fundamental physics as we intend it does not suggest ontological physicalism. (Ladyman et al., 2007, 44-5.)

Although physicalist, the NOSR of Ladyman and Ross is at best indirectly or tentatively physicalist, which is borne out by their later reduction of the ontology of science to stochasticity. The first sentence seems to assert universal continuity of structure, which would fit with the idea of structure reducing to the quantum field. However, Ladyman and Ross are not proposing such (I will.) Their idea is that I-obtaining structure is isolated or identified in a phenomena by constructed formalisms, but that additionally statistics also exists *in re* in the I-obtaining structure of the world. This brings my position very close to theirs, but there are still important differences. I agree with this conception of I-structures in the phenomena being picked out by formalisms, but like French [2] I regard that the content of the picked out structure is literally part of whatever material stuff the (structured) phenomena is constituted of (or else its dynamical and causal behaviour.) We may not be able to say anything conclusive about what the intrinsic material substance of the structure is according to my adopted interpretation of scientific metaphysics, which allows that both the nature of structure and what it may or may not inhere in can be contingently re-conceptualised and re-understood on the basis of the defeasible nature of contingent science and scientific theory. However, I think that scientific metaphysics, and especially this element of defeasible science - allows us to refer to the quantum field, and bounded regions thereof, as the substance of the structure about which ontic structural realism is realist. This is what I am calling the defeasible scientific metaphysical *identity* thesis about ontic structure: it's literally identical to selections of the structure of the quantum field and regions of it.

7.3 A New Informational Statement of Physicalism

I have already foreshadowed this in earlier chapters (see §1.4 p47.) An alternative statement of FRank Jackson's above formulation of physicalism will help to allay any suspicion of circularity or begging the ontic question: that I am assuming the physicalism of information to reinforce token physicalism.

7.3.1 Causal Continuity

My approach to causation in scientific metaphysical terms is an approximate adaptation of what has come to be called the 'spray-stuff' argument of Ian Hacking, an introduction to which conception (in conjunction with a description of my in-principle commitment to its basic premises) can be found at §3.4.3 p126.

[2] French, 2014

Important in physicalism about information is what I will call *causal continuity*. Causal continuity means that there can be no informational (information transmitting or carrying) covariance of structures (signals or emissions in science) and no causal inducement of a change in the configuration of one structure by another in the absence of continuous CICS (causal inducement of configuration of structure) causal pathways existing in CICS causal structures. Importantly, causal continuity does not require spatial continuity due to the obvious examples provided by non-local effects and in accordance with the Bell theorems, confirmed by later experiments (John Clauser and Stuart Freedman (1972) and Alain Aspect et al. (1981). See my discussion at §2.4 p72.) The recent re-validation of Bell's theorems suggest there is non-local causality with no intermediate field or other material structure: according to the best and most reliable scientific theory physicists have there is either an apparent or actual 'immediate' (possibly actually spontaneous) causal inducement of the configuration of one quantum system by another at a distance (Aspect et al., 1981; Freedman and Clauser, 1972 Cao, 2003c.)

This leaves potentially open the question of the specific nature of causality, but requires a continuous structure that can support non-contiguous causal transmission as a necessary condition. This non-contiguous continuity is easily characterised. If a signal passes between two points or locations in a structure, then there can be no causal (rather than spatiotemporal) 'gap'. This is not a-priori conceptual analysis or stipulation. It is a characterisation of the only known basis for signal transmission/emission through a physical channel, with allowances made for quantum entangelment. Ontic structural informational realism can tolerate counterfactual analyses of causation, but requires that they either accommodate or reduce to physical causation on a contingent metaphysical basis in accordance with our criteria for scientific metaphysics (Ney, 2009, 737-8, 740-1; Esfeld, 2010, 1598; Dowe, 2004.)

Say that it is proposed that there is a supernatural agent or structured supernatural entity. It is not clear how any kind of agent could have no I-obtaining structure at all, and I will posit that this is in fact impossible. Suppose our supernatural entity can interact with the CICS world to induce changes in the configuration of its dynamic and static CICS. Say the induced changes in the configuration of the material structure covaried with and were partially isomorphic with the configuration of some (dynamical) sub-structure internal to the agent, and thus constituted a signal or even a message.

Contingently, then, and setting aside cognition and sentience as irrelevant, that part of the putatively supernatural (and presumably non-material or at least spooky-stuff comprised) agent/structure that does the causal inducing must be causally inducing changes in CICS. That connected inducing/interacting part of the supernatural agent/structure has to be a CICS structure, or else it could not do so per the principal of causal closure (PCC) and primacy of physics constraint (PPC) both. However, then any other part of the supernatural agent/structure (also an information source if it is causally induces) that interacts with its causally inducing CICS part would have to be CICS also, by causal closure and casual continuity. I suggest principal of causal closure (PCC) and ontological principal of natural closure (PNC) both apply here, and that there is no version of naturalism that allows us to venture outside of their proscriptions without becoming not-naturalism. This in keeping with contingent scientific metaphysics: not only is it in principle impossible for physical structure to causally interact with not-physical structure, but - in accordance with our scientific metaphysics premises - such an interaction has never been scientifically-verifiably (publicly and experimentally) detected that we know of. The no miracles argument with vast inductive support puts a non-physical causal outcome at bay even for spooky action at a distance in QM. In response to the idea that some causality is non-physical according to - say - counterfactual causal analyses.

There are numerous interpretations of both counterfactual and physical causation (For counterfactual interpretations see Woodward, 2003; Broadbent, 2007; For opposing physicalist conceptions see Salmon, 1994; Kutach, 2013; Ney, 2009; See especially Ladyman et al., 2007, 258-62; 264-5; 275-6.) Counterfactual approaches tend to include, but are not limited to, at least these features:

1. Omissions and preventers as causes of outcomes, which coheres with the idea of causation being defined by difference making (rather than, say, physical causal pathways)

2. Causation in cause and effect involving compound or multiple possible causal pathways that all factor into the causal relationship in a cause-effect interaction.

3. Causation in cause and effect involving compound or multiple possible difference makers (including omissions and preventers), more than one of which can be taken to be a factor cause-effect interaction.

Counterfactual approaches come under the broad heading of difference making characterisations and theories of causality, and these are contrasted with the set of mechanistic theories of causality:

> Mechanistic theories of causality are normally contrasted with difference-making theories of causality. This heading includes probabilistic, counterfactual, regularity, agency and some dispositional theories of causality. According to a difference-making account, two events are causally connected if and only if a change to one makes a difference (of an appropriate sort) to the other. ... [This category distinction] can be flouted: e.g. one might give a mechanistic account which is essentially difference-making because the mechanisms in question are given a counterfactual analysis, or one might give a difference-making account which is at root mechanistic if the differences in question have mechanisms as truth-makers. (Williamson, 2011, 422.)

The CICS approach is closest to "causal foundationalism: the view that facts about difference-making are dependent on the obtaining of facts about physical causation" (Ney, 2009). Difference making interpretations of causation include such things as omission and blocking or prevention: omitting to take action constitutes a cause, for example (likewise - preventing some action constitues a cause of the outcome.) However, a number of theorists have argued that such approaches are confused (Dowe, 2004). My scientific metaphysical approach - with its inclusion of the *defeasible* nature of science and scientific contingency as centrally important - accommodates the approach of Braddon-Mitchell, 1993, who argues that a-priori difference making and other accounts of causation do not undo the in-principle existence of some microstructural process or interaction to be discovered my science contingently, and also coheres with the view of Chakravartty, 2005 that causal accounts that involve conceiving of causation "in terms of mere, regular or probabilistic conjunction are unsatisfactory, and that causal phenomena are correctly associated with some form of de re necessity" (Chakravartty, 2005, Abstract.)

Historically, scepticism about the nature and existence of causality has strong supporters - including David Hume and Bertrand Russell. However, the scientific metaphysics that I espouse coheres with the argument of Chakravartty's process theory of causality:

> that if such objections seem compelling, it is only because everyday expressions concerning causal phenomena are misleading with respect to certain metaphysical details. These expressions generally make reference to the relations of events or states of affairs, but ignore or obscure the role played by causal properties. I argue that on a proposed alternative, an analysis in terms of causal processes, more refined descriptions of causal phenomena escape the charge of incoherence. (Ibid.)

Process theories usually fall under the head of mechanistic theories of causality (Salmon, 1994; Glennan, 2010), and the CICS-FOSIR approach also accommodates significant aspects of that approach. CICS doesn't require properties, per se, but the causal inducement of configuration of structure could fairly be regarded as a process - especially by the standards of physics where finite amounts of time are arguably necessarily required for such inducements (with a possible exception being available along the lines of the possibility of Planck-scale ontological fundamentally discrete nature.) In formal classical Shannonian information theory and in contemporary information theory, sources are of course stochastic physical processes. So the kinds of causation required by CICS is very much that which can induce a configuration or pattern in the dynamical structure of a source. Given that signals and channels themselves can be treated as sources, this tends to impute a process aspect to causation in classical mathematical communication theory in general. In fact, I've been arguing that causal stochastic processes are ineliminable necessary conditions for the obtaining of information, as well as for its transmission. With these reminders in place, one can see the relevance of the process theory of causation presented by Wesley Salmon as reported by Williamson:

> The idea behind the process theory is that A causes B if and only if there is a physical process of the appropriate sort that links A and B. There are two views as to which kind of physical process is appropriate for underpinning causal relations. One view has it that the process should be one capable of transmitting a mark from A to B (Reichenbach 1956, section 23; Salmon 1980a, section 2). According to the other view, a causal process transmits (Salmon 1997, section 2) or possesses (Dowe 2000b, section V.1) a conserved physical quantity, such as energy-mass (Fair 1979), linear momentum, angular momentum or charge, from A to B Williamson, 2011, 423; See also Salmon, 1994;)

Physical causal arguments and counterfactual causal analyses are either about different things, in which case some of the counterfactual analyses are not relevant to the nature or information as necessarily transmittable, or else they are very different analyses of the same thing, which is contingently to be explained reductively (Ney, 2009). Where cand if ounterfactual causal analyses undo the principal of causal closure (PCC) and *ontological* principal of natural closure (PNC), or require the elimination of physical causal structure somehow, I reject them. Incidentally, the thought experiment I'm here describing (supernatural/spooky causal pathways) with its CICS ontological-status 'domino effect' constitutes also an alternative statement of ontological principal of natural closure (PNC) (the only principal of natural closure (PNC) I am calling upon.)

Returning to our thought experiment, Spooky-stuff Supernatural causal agency or inducement that changes the configuration of CICS in the physical closed universe is therefore a straight paradox. The inducing agent/structure can only be CICS, and therefore a material and thus natural agent. This requires that principal of causal closure (PCC) is the necessary and sufficient condition for what is natural, which reconciles with the materialism of physics. All information reduces to CICS construed according to FOSIR (defeasibly) in the causally closed universe according to a scientific metaphysics.

Continuous causal pathways are best defined as follows. If there is a causally inducing structure A and a casually induced configuration of a structure C then there must be either 1. direct immediate or non-mediated causal inducement of C by A, or else 2. indirect causal inducement of C by A through n intermediate causal CICS pathways which are themselves CICS, between which there is immediate or non-mediated causal contact. Non-mediated causal contact means that there is direct causal contact between the two structures with no intermediary structures or causal pathway elements. It is physicalist non-eliminative structural realism with the QFT-OSR identity thesis that is providing the ontology. In the FOSIR ontology structure (realised at bottom as physical fields) is ubiquitous. Thus non-mediated direct causal contact between structures must happen at the smallest possible physical scale: say (contingently) Planck distance.

As I have just indicated with reference to the Bell theorems, there is an exception in the context of quantum entangled states or what Einstein called "spooky action at a distance" (nonlocal effects) in quantum mechanics. With entanglement measuring one of a pair of spatially separated quantum systems (particles) affects the state of the other system with no apparent intermediate causal structures or pathways (hidden local variables.) However, it remains that with entangled quantum states of particles and quantum systems exhibiting action at a distance, the altering of the state of one system reliably always results in the inducement of a predictable change in the configuration of the state of the other system. Moreover, in accordance with the informational eliatic principle

Whatever kind of specific causality is involved, physics takes it to obey causal closure. Thus action at a distance for entangled quantum systems does not contravene causal continuity under causal closure (principal of causal closure (PCC) via primacy of physics constraint (PPC).) Instead, there is just no requirement in terms of shortest possible distances (non-contiguous.) Whether the casuality involves intermediary CICS (hidden local variable interpretation) or not, it is still physical. Specific types of physical cause - causally altering the configuration of the state of one of the systems - results in physical effects in the configuration of the state of the other system on a regular and predictable basis (even in the context of density functions.)

7.3.2 Informational Ontological Closure

Causal interaction with the CICS informational universe is a sufficient condition for the upstream casually-inducing interactor to be itself *I* CICS and therefore physical and natural. This is defeasible and comes by way of induction from scientific findings in physics. The interactor is also a CICS information source. CICS physicality is like an ontic domino effect: all the dominoes have to be *I* CICS (which means physicalist ontic structural realist) and obey causal continuity under causal closure. Anything in the informational causal chain of structures is contingently or naturally necessarily physical. Contingently and according to our best applied scientific and applied mathematical theories of information in mathematical communication theory and algorithmic complexity theory (and computability theory) CICS are a necessary and sufficient condition for the embodiment, encoding, processing, and transmission of real information (and of data on most characterisations thereof, with the notable exception of Floridi's ontological neutrality posit.) Causal pathways are a necessary and sufficient condition for information transmission. (Dretske, 1981, 26-8.))

A consequence of the CICS conception of information is that information processing and transmission is causally closed: informational structure-entities (sources) have the necessary condition that they obey causal closure, and thus so does information.

Say any kind of apparatus that was constituted of existing physical natural kinds (matter, energy etc.) could detect some new ontic stuff. This would mean that there would have to be a physical causal interaction based upon causal pathways that are also *I* CICS existing between the contingent new stuff structure and the known physical stuff of the apparatus: one that could carry information or sustain real information transmission. Both would have to be CICS: extended and causal. This is the compliment to the supernatural agent thought experiment aboveI will refer to this as *informational* continuity: the causal pathways necessary to induce representations of information of the new stuff into the structure of the measuring device would have to be continuous under the principle of causal closure. This includes quantum entanglement, since Ontic structural informational realism, and later FOSIR, require only causal continuity, not I-contiguity.

If there is no possibility of such spatiotemporal causal inducement of the configuration of the measurement apparatus by the new spooky stuff source S^s, then the new stuff is not physical, nor causal, and no information could ever be transmitted from it, nor encoded from S^s, nor, I suggest, would any information *about* S^s be available. Accordingly, all of the following would hold:

$\neg\exists *_i^\theta S^s$ (that - semantic information encoded from the source indicating something of its configuration, nature, status, state, or dynamics/behaviour)

$\neg\exists *_i^\iota S^s$ (in - within source structural boundary, including in mathematical representation)

$\neg\exists *_i^\omega S^s$ (of - within the source including its boundary)

$\neg\exists *_i^\alpha S^s$ (at - at the source and its immediately causally connected sources per causal continuity)

$\neg\exists *_i^\rho S^s$ (artefactual representation)

$\neg\exists *_i^\nu S^s$ (natural representation)

$\neg\exists *_i^\phi S^s$ (from - any structure encoded from the source into other sources via the inducement of configuration/pattern)

$\neg\exists *_i^\theta S^s$ (that - indication by signal transmission)

All of the following also hold because there's no transmission and no emission possible in principle from the spooky stuff source to any real informational non-spooky source:

$\neg(S^s *_i^\sigma S^j)$

$\neg(S^s *_i^\eta S^j)$

There is no partial representation available either:
$\underset{i}{\Delta} *_i^\phi S^s = 0$ (refer to §1.3.1 p45 and §1.3.1 p44)

It follows from the above *in epistemic terms* that S^s DNE (does not exist). These operators are intended to be physico-logical cum quantitative operators. The same argument and operator can be applied to platonic entities in the same way. The physico-logical operator component mimics that proposed by Paul Humphreys for dealing with emergence (Bedau and Humphreys, 2008.) The addition of the dual duty as quantitative is motivated by the need to overcome the qualitative-quantitative gap in information measures in classical theory. This operator is both quantitative and logical: the quantity of information transmitted to any other source is 0, and there is correspondingly no transmission from S^S possible (2nd order modal logic.)

There can be no causal discontinuity with any informational processes including transmission and encoding. This also means that it is not circular to say that only real structures can be informational, and only CICS are real structures. The determiner and necessary condition for physicality is neither spraying (Hacking, 1983) or microbangings, it is informational causal closure reducing to transmissability (See also the development of IS1 later at §4.6 p171.)

The point is that if the kind of causal pathways that are required for all material measurements of matter and energy and other known physical natural kind types can be set up between known physical stuff and any new stuff, then the new stuff is CICS-informational and could not be discovered physically otherwise. In principle it could necessarily could never be discovered from a informationally causally closed universe. Causal closure is informational closure, and informational continuity is the necessary condition to get any signal from or representation of the information in a real source.

There is another way of stating the physicalist necessary and sufficient conditions of information realisation:

- IP_1 (Informational Physicality): A physical duplicate of the world simpliciter is a complete informational duplicate of the world.

IP_1 is an adaptation of Frank Jackson's statement of physicalism - that a physical duplicate of the world is a duplicate simpliciter. It is a duplicate of everything that exists without exception or omission which says that if one duplicates all of the physical structure of the world, then one will have duplicated all of the information associated with and realised in the world (Jackson, 1998, 9, 18-30; See also French and Ladyman, 2003b, 75.)

The above development is evidently Armstrongian - relating to the eliatic principle in informational terms. However, my overall scientific metaphysics is not Armstrongian, because I have rejected his variety of nominalism. Thus the question arises about its correctness in ontological terms. It doesn't seem right to deny a source has existence on a logical necessary *and* natural necessary basis when such a spooky source may well exist - like another Lewisian modal realist possible world - but be in principle perpetually causally inaccessible to us: to the actual world of veridical sources. There are standard responses to this, including that which compares the case to that of an entity our source structure that is part of the physical world according to causal closure (i.e. - it's not a spooky source). The idea is that this kind of as yet undetected source is necessarily in principle not informationally inaccessible. However, the informational pathway picture that I have deployed *entails* that the source in question - the non-spooky source outside of our light cone or otherwise undetectable - is naturally necessarily connected to every other source realised in the quantum field by multiple channels. In other words - there are channels which meet the boundary of our light cone and go beyond it. That means that there are causal signal pathways connected to it from both myself and the reader right now. We may never be able to propagate a broadcast signal to them within any imaginable reasonable time frame (the message might not be received before our solar system is long gone - for instance). However, if we somehow acquire enough energy or power to do so (enough to penetrate any noise and overcome signal loss) then the signal - or part of it - would necessarily reach the out of light cone source provided it still existed and was not moving away faster than the signal speed (We also have to consider the CICS-FOSIR.)

It follows from the above that everything that exists realises information and therefore reduces to physical structures or supervenes (reductively) upon physical structures (French and Ladyman, 2003b, 42-50.) As an adjunct outcome: anything that is not informational in this way is not real (see also §4.4 p158.)

My positive I CICS physical realist and physicalist thesis about the ontic nature of information culminating in IP_1 is supported by a negative anti-Platonist thesis (§1.4.1 p49 and §1.4 p47) about what information could not be.

7.4 Some Anticipated Responses/Problems (to elements of the metametaphysics of FOSIR-CICS source ontology)

7.4.1 Eliminativism and Pluralism

Research into protein folding involves numerous explanatory challenges including 1. how proteins come to be efficiently folded into a natured state so that they are functional (Biro, 2013; Wolynes, 2008; Gershenson and Gierasch, 2011; Horwich, 2011; Dill and MacCallum, 2012; Weikl and Dill, 2007) and 2. the related but prospectively harder problem of how protein folding mechanisms evolved or developed in the first place (Wolf and Koonin, 2007; Bernhardt and Tate, 2010.) The first is the kind of process that Sahotra Sarkar has described as being a prime candidate for a information theoretic and semiotic description which recognises *conformational* and *dynamical* information as I-obtaining in the structure of the system (Sarkar, 2006.)

Yet the general and well known survey of the protein folding problem by Dill et. al. mentions the term ‘information’ only once in 27 pages, albeit with fairly significant information theoretic and ontological import:

> The search for folding mechanisms has driven major advances in experimental protein science. These include fast laser temperature jump methods. . . ; mutational methods that give quantities called θ-values . . . [now also used for ion-channel kinetics and other rate processes (42)] or ψ- values (204), which can identify those residues most important for folding speed; hydrogen exchange methods that give monomer-level information **about** folding events (Dill et al.,

2008b, 294-5.) (the term 'encoding' is also mentioned only once at 291.)

The role for the reference to information here has nothing obvious to do, however, with I-obtaining structure in protein folding microsystems. It appears to be only referring to epistemic-explanatory benefits associated with the experimental and analytic methods described. This impression comes primarily, I suggest, from the 'about' term, and from a somewhat epistemic/subjectivist interpretation of the nature of information (probably with some reference to the classical theory.) I will refer to this usage henceforth as corresponding to the lexical representation or 'about' dynamical information logic operator ($*_i^\nu$ - see §1.3.1 p44) to be read as 'information about σ' where σ is a source structure. Suffice to say, it does not look (from the above passage) like Dill et al., 2008b have much use for realism about information or associated concepts in the fairly hard science of protein folding, and so my indispensability argument appears to have hit a snag in this case.

Correspondingly, one view that causes problems for the realist argument is ontological eliminativism about information in the philosophy of biology. Some philosophers of science and biology have argued that in biology and especially the molecular biosciences, the term 'information' (and closely associated terms like 'coding', and 'code') can be regarded only as either simply a convenient term of art, a useful metaphor to refer to various different physical constructs and dynamics (Griffiths, 2001; Griffiths and Stotz, 2013, 143-5.) Eliminativism is related to *pluralism* in so far as the latter, drawing on a nominalist conclusion from theory level pluralism about information, denies that information exists as any central natural kind, basic existent, or primitive particular based structure (or perhaps structural type.)

How to save my fairly important indispensability of information argument from this apparent dispensability of informational terms and information in a field where transmission of configuration of structures by various dynamical mechanisms is certainly ineliminable in an I-ontic sense? Returning to Dill et al., 2008b, it is undeniable that the job of the DNA, tRNA, ribosomes, chaperone molecules, and/or chaperonin is to structurally guide the folding of the polypeptide chain into its natured state: to induce the appropriate configuration of its structure. This requires causal inducement of structures from alphabets of structures drawn from the configuration of various sources: the mRNA, and before that the DNA, as well as the functional structures of the ribosome and its rRNA and the structures of the chaperonin themselves. These various structures are modular and uncontroversially form natural modular sequences of symbols, and their structures causally induce downstream configuration in other structures. Their configurations can be measured as entropy and as complexity, and in a sequential sense as Markov sequences: the measures that can be devised are multifarious and can involve statistics and various mathematical constructs.

A support for a less severe *pluralism* about biological information is that several senses of the term 'information' are used by molecular bioscientists and philosophers of biology to characterise the nature of biological information, and several more have been proposed as unifying and/or central. They include:

a. The classical sequence and/as encoding sense familiar from the fundamentals of genetics, (Godfrey-Smith, 2000; Godfrey-Smith, 2007)

b. The Peircian semiotic or signification and signalling approach proposed in part by Godfrey-Smith and related to work by David Lewis (Godfrey-Smith, 2001; Godfrey-Smith, 2011; Lewis, 2013.)

c. What Carl Bergstrom and Martin Rosvall have called the transmission sense of information as applied to the informational characterisation of genotype to phenotype transmission in DNA transcription and translation and protein synthesis (Bergstrom and Rosvall, 2011),

d. The conformational conception of information associated with the stoichiometric and chiral properties of biomolecules (molecular angles and their degrees of freedom, for example) in processes such as protein synthesis and folding (Sarkar, 2006; Sankararamakrishnan and Weinstein, 2000.)

e. A combined semiotic conception that includes sequence specificity, conformation, and dynamical elements - also proposed by Sarkar.

f. The teleosemantic conception of information in biology derived from philosophy of mind (Millikan, 2009, Millikan, 2001.)

g. Nicholas Shea's *infotel semantics* which requires/includes "correlational information" and "starts from the idea that genetic transmission is a way for organisms to send signals to their offspring, and seeks to define the semantic content of those signals." (Shea, 2007a; Griffiths and Stotz, 2013, 165-7.)

h. The functional-cum-infotel semantic conception of genetic information recently proposed by Griffiths and Stotz (Griffiths and Stotz, 2013.)

i. The pragmatic Bayesian subjectivist approach of Ariel Caticha (Caticha, 2014)

If eliminativism about information is either true (correspondence semantics true) or correct (correctness of some formal theory), then realism, let alone physicalism, about information, can't get started. To begin with, however, it is at least not clear that the propensity for scientists and philosophers to use the term 'information' plurally and polysemously - even using an apparent correspondence theory of truth - entails that anti-realism about information is true. The term 'structure' gets used comprehensively in scientific theories in a polysemous manner, but it does not seem coherent to claim that structure is not real on this basis, nor that when scientists describe physical structure that they consider this to be ambiguous, nor that they consider structure to be a fiction (with allowances for the difference between mathematical structure and physical structure.) The tenor(s) of 'information' as a metaphor are usually Shannonian theoretical terms like 'information', 'encoding', 'transmission', 'channel', 'noise' and 'decoding' (The term 'code' does not appear in Shannon's Mathematical Theory of Communication, although source and channel coding are certainly familiar from contemporary mathematical communication theory - Dretske, 1981, 115-116; Gallager, 2008, 7, 64, 249-50; Orlitsky et al., 2004, 1469; Shannon, 1998, 1, 2, 5.) Otherwise they are regularly terms inspired by complexity, computability, or sequence orientated conceptions like those of Crick and Watson (the sequences being very much physical structures and representations thereof) and hybridisations with Kolmogorov complexity and its derivatives (Wolf and Koonin, 2007; Galas et al., 2010.)

The active scientific use of more than one of a.-i. presents a problem for a non-pluralist and reductionist realist view (Sarkar, 1998; Godfrey-Smith, 2007; Godfrey-Smith, 2001.) It often doesn't look like molecular bioscientists and philosophers of biology are saying that there is a singular reductive conception of information, and philosophers of biology have been known to assert anti-realist positions, and nominalist-like positions. The reductionist physicalist realist about information (me) has arguably only three options - give up realism about information, or identify what in the ontology constitutes the basis of information in all theories on a non-trivial basis, and/or identify when scientific theories are not really referring to information at all but simply being terminologically imprecise or lax. The correct question is not "What justifies the claim that a scientist who is a subjectivist/pluralist/probabilist/computationalist about information is not just legitimately talking about a different kind of information?", but "Is there something - common to other conceptions of information - that the scientist is referring to in the ontology, or something in the ontology that is ineliminable as the existential basis for what the scientist is referring to?" and, importantly (to avoid redundancy and vacuity) "Is that thing more than just structure?" According to a scientific metaphysics, information may be being referred to using various other terms.

The question is whether it follows from the existence of plural conceptions of information in the molecular biosciences that there is no common reductive ontic foundation of various references to information. This can be seen to be a parallel to the question of realism about structure - and especially the relationship between structure and content - in the ontic structural realist debate. I am suggesting that it is an extension of that debate since I am offering an ontic structural informational realism as a basis for the metaphysics of information. It does not follow from there being a. through i. in molecular bioscience and philosophy that anti-realism about physical information is true, nor that nominalism or pluralism about an ontic primitive ground of biological information itself - rather than measures thereof - are true.

I take a primary non-negotiable identifier and sufficient condition for the presence of information to be signal transmission including natural and/or artificial transduction/quantisation reducing to causally induced and incidentally/naturally representing structures (they represent in the same way as a footprint in the sand represents the foot that made it, and in fact by extension all feet due the causal genetic pathways that connect all feet to one genetic ancestor.) I think that transducer based natural and artificial encoding/encodability with nomic constraints (and certainly with natural alphabets of structures or possible configurations) are also a sufficient condition.

I can offer some preliminary idea of what the more specific distinguishing features of information-indispensable theories might be. I suggest that they tend to be theories that either:

I. Have some kind of apparently I-obtaining information as their central object of study and especially where

   I.1. Such theories deal with experimental results and repeatable experiment and derived data: i.e. are not based upon simulations, forecasts (as in applied computer science for the soft sciences or special sciences), or undetected postulates (as sometimes arise in particle physics for example.)

   I.2. The information in question is assumed to occur naturally and not be an artefact of the theory or experiment in instrumentalist or pragmatic terms. i.e. The science is done with the express intention that some kind of natural environmental information is supposed to be its object.

II. Involve modeling and/or identifying some kind of environmental information *transmission* involving signals and/or emissions, and/or signal (and therefore symbol/message) encoding/decoding, and/or processing, and/or generation/production where these processes and dynamics are considered to be physical and causal in some important sense. (Godfrey-Smith, 2014)

Such cases very much seem to involve an assumption of the existence of information as an I *commodity*. In many cases it seems that the commodity in question is not in fact regarded as abstract (see the examples from Demirel et. al, Gattenby et. al, Dill et al., and Singleton et. al in the previous section), as Dretske described (Dretske, 1981; Devlin, 1991.) These kinds of theories should be distinguished from theories that seem to use references to information only in an illustrative or non-critical manner. These ideas constitute the beginnings of a positive scientific metaphysical argument for the I existence of information.

In contrast to biology, physics seems to be less ambiguous about information as an indispensable component of empirical theories *and* as physical at bottom. Still, physicists tend to apply classical information theory and derivatives thereof with surprising variability in theory construction and in the interpretation of information theoretic terms. Moreover, there have been efforts to use algorithmic conceptions of information and complexity and to unify these with classical probabilistic formulations (Vitanyi and Li, 2009; Grünwald and Vitányi, 2003, and especially Chaitin, 1975, 329-31.) Then there are cases where there looms the formal-physical duality that French refers to under the rubric of the collapse of represented structures into representing structures prevails (French, 2014, 133-4, 192-3), and other cases where there is a clear mathematisation of the ontology on Everettian or other terms (Tegmark, 2008; Deutsch, 1998; Everett, 2012.)

7.4.2 Triviality and Token Physicalism

I have already extensively alluded to this objection, and dealth with it by presenting alternative realisms about information including various ontic structural, Platonic, Kantian transcendental, and statistical realist versions. In this section I will say more about the pancomputational and computationalist realisms about information as data and the 'it from bit' ontological view.

The ontology about which I am realist places physical structure at bottom as the existential reductive basis of information as well as everything else. To use a very truncated thought experiment to clarify my overall intention: if we are all in a giant advanced computer simulation as Nick Bostrom has hypothesised (Bostrom, 2003; Bostrom, 2009), then the simulation and the information processing in it reduces to physical structure. Redundancy and overdetermination aside - any alteration to the physical structures including the causal pathways necessarily results in a change in configuration of structure and of the information of the structure, and therefore results in changes in the simulation in qualitative informational terms.

So one of my core claims is that no real information exists where there is no I-obtaining physical structure, and this is because without physical structure there is no causally induced configuration of physical structure - which reduces ontologically to nonuniform physical I physical fields which must all reduce defeasibly to regions of the fluctuating quantum field - which is the proposed reductive basis of all real information. This is not only not a vacuous restatement of token physicalism. Neither is it just uninteresting since many information theorists and even mathematical physicists have proposed that the universe is in fact information at bottom, with no Landauer-style ontological commitment to physical structure as a necessary condition for the obtaining of information or it's representation, while scientific anti-realists insist that the ontological nature of the referents of scientific theories and their models is in-principle inaccessible (Floridi, 2008a, 241-2; Floridi, 2011c, 361. See also Tegmark, 2008, Bostrom, 2003; Van Fraassen, 2001; Van Fraassen, 1991; Van Fraassen, 2008)

The original computational metaphysics is arguably due to computing pioneer Konrad Zuse who proposed in the 1950s that the universe might be running on, or as, an enormous computer (Floridi, 2009a, 152-3.) Restatement of this came from physicists Edward Fredkin and John Wheeler's 'it from bit' thesis.

Pancomputationalism is characterised by additional posits present in the theories of Zuse, computer scientist Edward Fredkin and to some extent by that of mathematician Stephen Wolfram (Bynum, 2014, 125-6.) One of these is identified in the final sentence of the above quoted passage. Fredkin's theory requires that nature be regarded as necessarily discrete at a fundamental level digital and that there be no ultimately continuous processes in nature. In this, Fredkin embraces Einstein's assertion of the discrete nature of quantum phenomena and objects:

> One can give good reasons why reality cannot at all be represented by a continuous field. From the quantum phenomena it appears to follow with certainty that a finite system of finite energy

> can be completely described by a finite set of numbers (quantum numbers.) This does not seem to be in accordance with a continuum theory, and must lead to attempts to find a purely algebraic theory for the description of reality. But nobody knows how to find the basis for such a description. (Einstein, 1950)

However, Fredkin maintains that the solution is not to be found with algebra but with information theory, and that according to his finite nature hypothesis the universe is not only computational by virtue of being fundamentally digital but effectively also itself a computational process (Fredkin, 1992, 116-17. See also Zenil, 2013, 3-5; Vedral, 2010; Brooks, 2012a; Brooks, 2012b; Beavers and Harrison, 2012, 349-51; Chaitin, 2012, 280-1; Hutter, 2012, 408-12)

It seems to be an article of faith among many philosophers of information that the information in a given spatiotemporal volume must be finite. The primary contingent reason for this is probably the Bekenstein bound on the amount of information required to describe any physical system occupying finite space and with finite energy, and the Bekenstein-Hawking entropy which demonstrates that the bound is saturated (it's limit reached) for three dimensional black holes (Bekenstein, 2004; Müller et al., 2012.) However, it is noteworthy in the context of both the difficulties involved with and the defeasibility of scientific metaphysics the formulation and scope of the Bekenstein Bound is debated, and that according to contemporary information theory (specifically mathematical communication theory) information sources can have both unknown and infinite possibility spaces or alphabets, which latter translates to infinite information according to most information-theoretically derived conceptions [3] (Gallager, 2008, 16, 71-2, 85; Orlitsky and Santhanam, 2003; Hayashi, 2017, 599.) Moreover, Shannon's classical formulation of information measures for continuous sources (continuous physical stochastic processes) is achieved by imposing the discrete source solution upon them for mathematical tractability (Shannon and Weaver, 1949.) The upshot is that Shannon's classical characterisation and model of continuous sources is inherently a partial representing mechanism (For further discussion including reference to Einstein's discretising conception of the universe and Planck length, see §4 p137, 101.)

Adriaans and Van Bentham refer to approaches like Fredkin's under the broad heading of "metaphysical computationalism", and the Zuse and Fredkin varieties are only one of a number of proposed models (Adriaans and Benthem, 2008, 12.) Computational metaphysics has been variously endorsed and developed by philosophers, and there is an entire new field of scientific endeavour which regards nature as computational but which does not necessarily involve regarding nature itself as a simulation or as fundamentally informational in ontological terms. This does not require Wheeler's "It From Bit" ontology, but does allow it (See Dodig Crnkovic and Giovagnoli, 2013.) My approach allows for the coherence of the idea of nature as computational and informational, but involves rejecting Wheeler's ontological stance as arising from an illegitimate

[3]It certainly should for a view like that of philosopher David Chalmers, according to whose controversial characterisation possibility spaces *are* the information. (Chalmers, 1996)

extrapolation from facts based upon an apparent bias towards a form of instrumentalism or a kind of Van Fraassen style constructive empiricism. According to Wheeler, nature is informational because the way in which we investigate nature using instruments involving testing binary possibilities or - in Wheeler's terms - asking binary questions.

My view of Wheeler's computational metaphysics applies also to the informational metaphysics/ontology of Luciano Floridi (Floridi, 2008a, Floridi, 2011c), which I also reject as premature and not supported by science as a scientific metaphysics, despite the role of statistics and computation in the sciences. If it was clear that reductionism was completely undone as a going concern in science it would not follow that the universe is informational at bottom It is far from clear that such is the case, and I think information theory can be shown to bear out the opposite.

I am minimising the *I* ontology by asserting that *representing* structure in models and theories picks out just partial structure and therefore partial information in and of a system (French, 2014, 102-3.) The debate about real versus mathematical/formal structure brings out an important point: there are theorists and philosophers who think that some real structures are non-reducible non-physical Platonic abstracta. As with the CICS formulation - or with any formulation that regards that information is somehow realised by structures - in the cases where structure is taken to be Platonic or transcendent non-physical, Platonic abstract, and irreducible supervenient and prospectively non-physical structures are informational. The upshot is that according to those approaches information is *not* physical, although as I have argued previously (§1.4 p47), it is not only not clear what it is, but how it can have the property of being informational or of informing anything - or any mind for that matter.

In accordance with these observations about pancomputationalism and platonism about information, physicalist reductionist realism about both structure and information is not token physicalism. The idea is that *real* information reduces to physical causal CICSs as an existential necessary condition.

7.4.3 Reductionism

A defence of either physicalism or reductionism is very large scope work. I am limited to an indirect approach to retaining reductive physicalism by identifying its indispensability. Regarding indispensability of physicalism, Ladyman and Ross defer to the primacy of physics constraint (PPC) (Ross et al., 2013, 37.) I think it is fairly uncontroversial that physics largely takes physicalism to be true.

It is apparent that the reason for the epistemic privileging of physics is not just about scope, but about the reduction of explananda to ontic explanans. Now, it might be true that a field biologist studying the epigenetic features of a mammal species is no more interested in, and needs to use no more references to (none at all), quantum systems that are the material microstructural basis of their samples than does a carpenter. A molecular bioscientist trying to understand chaperonin operations in protein folding and the stoichiometric limitations associated with the same, on the other hand, may well have cause to investigate the degree to which quantum effects are a basis for and impinge upon protein folding dynamics and the transfer of information from one point in the chain of protein synthesis to another (See §3.3.1 p111p 110-11 .) Correspondingly, while not being thoroughgoing reductionists, Ladyman and Ross are not anti-reductionist. They present a set of naturalistic principles for theory unification and scientific metaphysics that cater for the importance of certain kinds of physical or ontological reduction (what they call 'core-sense reduction'):

> [W]hile we are not type reductionists...the realization argument tells against that doctrine, we are also not proponents of the sorts of non-reductive physicalism (involving token identity and/or local supervenience) paradigmatically associated with the rejection of type reductionism...*Core Sense Reductions* are also sometimes called 'ontological reductions' ... (CR) All nomic special- and honorary-scientific facts, and all positive non-nomic special-and honorary-scientific facts, have an explanation that appeals only to (i) physical facts and (ii) necessary (i.e. non-contingent) truths. (Melnyk 2003, 83.) (Ladyman et al., 2007, 51.)

This kind of reductionism caters for the kind of NOSR that identifies relations as ontologically fundamental. It does so by allowing the ontological status of relations to be based in significant part upon necessary and logical truths. This is one way to sure up the portability of one kind of relation between physics and mathematics, which is arguably of critical importance given the obvious interdependency of the two. This portability of the nature of relations is a central feature of the NOSR of Ladyman and Ross, but per criticisms that will be discussed in the following section: this is one point at which it could be argued that the a-priori manages to becomes part of the ontology of relation based NOSR. However I will retain this kind of non-type reductionism at minimum (although not with relations as the ontic base), and do not see any point in not adhering to this statement of it. It seems well suited to accompany an NOSR according to which structure reduces to heterogeneous fields rather than relations (§6.6 p242.) A contingent scientific and thus defeasible metaphysics must make reference to physics. In fact physics - and particularly QFT - will very directly provide the basis for the kind of adaptations that I will make to physicalist NOSR.

7.5 Conclusion

Most significantly in this chapter, I presented a new informational statement of physicalism, which is intended to strengthen the best existing conception of physicalism. My interest in this is obviously that it helps support the scientific metaphysical FOSIR-CICS source ontology that I have presented in the thesis. To this end I revised David Armstrong's a-priori analytic (in fact Armstrong's metaphysics is significantly contingent) eliatic principle, developing an information theoretic version which defeasibly defers to FOSIR. This is by way of an argument that there is no information without the right kind of physical spatiotemporal structure, and that in fact all information must reduce to very specific feature of such structure(s) (their configurations or arrangements.) I then adapted Frank Jackson's statement of physicalism in such a way that the circularity complaint against Jackson's version is nullified.

I went on to anticipate three key challenges and problems for the view and its foundational concepts, including challenges from pluralism and eliminativism about information, and charges of token physicalism. Platonism, mathematical ontic descent, and probabilism (statisticalism) were addressed in earlier chapters.

I'm certainly not trying to argue for realism about information as some kind of new element or natural kind. It is obviously not a parallel case to realism about a new type of particle suggested to exist on the basis of the theoretical work of particle physicists. It is, however, analogous (more than analogous) to the idea of realism about I-obtaining structure. If information is or reduces to I CICS, and if CICS reduces to and is identical to nonuniform fields, then this reconciles with the idea that there can be no information transmission without signal transmission through I-obtaining mediums, and the idea that real information is intrinsically representational and thus semantic and must be causally interactive in such a way that it can be thus transmitted.

So leave aside for the moment the question of whether ontic structural realism or any structural realism is a correct scientific metaphysics. Regardless, if information exists as a certain set of effects and outcomes associated with and realised by CICS structures, and if structure is I real - then information is arguably I real. The causally induced configuration of real I (field reducing) structures is something real. Given the ubiquity of configurations of spacetime and fields that are important in physics and in metaphysical observations motivated by physics, information is also ubiquitous. It is and reduces to the causally induced configuration of structure which - according to my radically minimalist view - just is non-uniform I fields. These same fields are the basis of structured causal pathways required for the transmission of a signal.

Part IV

Conclusion

7.6 Conclusion

My overall objective has been the naturalisation of information on physicalist and unusually reductive terms, but with deference to a scientific metaphysical outlook that incorporates defeasibility of contingent metaphysical posits in keeping with the primacy of physics constraint. In name, the ontology support the naturalisation of information is FOSIR-CICS source ontology: the field ontic structural informational realist, causally induced configuration of structure(s) (as) source(s) ontology. According to Steven French - we should read our ontologies off our best scientific theories and can chose a-priori metaphysical posits and representations if they are apt to the task of furnishing contingent metaphysics. I agree with the first part of the conditional, with the additional requirement that those structures thus regarded to be real should be informational and capable of sustaining transmission. I think that the second part of the conditional statement probably involves a-priori metaphysical posits and representations that are really significantly contingent My position is that it is better to rely upon what science adduces is already probably in the ontology: sources (stochastic processes) reducing (or in the real patterns sense - practically supervening upon) bounded regions (including distributed regions) of dynamical heterogeneous quantum fields and their ephemeral configurations.

According to James Ladyman, Don Ross, and Harold Kincaid, the world is the totality of nonredundant physical I-existing (my notation - introduced at 1.3) statistics, where those statistics are realised by stochasticity in re to/of natural stochastic processes. Julian Barbour and I agree that the world is comprised of configured information sources, but we differ significantly about how they have semantic content. Barbour's approach regards natural information as alethic and a truthbearer in accordance with earlier work by Fred Dretske, H. P. Grice, and Stampe, 1977. I regard this as a conflation of the concepts of a representation with that of information, and I have argued that representations, whilst also realised as CICS structures or structures that reduce to or else supervene upon them.

However, deferring to the defeasibility of scientific theories and explanations where these are the encoded representations of the I-universe in theory-models and their various physical min-dependent lexical, computational, and diagrammatic implementations: this does double metametaphilosophical duty. It allows me to make identity statements (H2 4) that are not a-priori fixed claims but contingent and revisable, and it thus helps me to avoid committing to the kind of formalism driven ontological assertions from theory that tends to impose them in an inappropriate way on the I-ontology.

It's not been my project nor my intention to attempt to subsume all statistical-quantitative and semantic theories, notions and conceptions of information under some all-encompassing unifying theory. Certainly not at all levels of abstraction or explanatory levels. The reductive physicalist conception of information and information realisation that I presented is not some overarching theoretical abstracta or all-encompassing theoretical concept or construct that unifies all theories of information at the level of their mathematical constructs and measures (Floridi, 2004a, Location 957.) My project has been to develop a scientific realist metaphysics of information itself. In Chapters 1 and 2 I established a metametaphysical and meta-philosophical basis and context for my project: contingent, defeasible scientific metaphysics. I then adapted the physicalist non-eliminative ontic-structural realism of the kind formulated and favoured by James Ladyman, Don Ross and Steven French to produce OSIR: ontic structural informational realism. I deferred to such NOSR as a correct and scientifically coherent conception and definition of the kind of structure the causally induced configuration of which I claim information reduces to: CICS. According to this conception of NOSR, all structure is physical or reduces to physical structure (French and Ladyman, 2003b, 17; Floridi, 2008a.)

I distinguished OSIR from ISR - Floridi's informationist NOSR adaptation - by demonstrating that OSIR is physicalist, non-transcendentalist, and reductionist, and by interpreting Floridi's idea of a nonuniformity in a non-binary way. I then added a defeasible scientific metaphysical ground for OSIR in QFT by asserting a brute identity of the structure of OSIR and structures that reduce to nonuniform heterogeneous regions of the quantum field. I also made the fairly radical adaptation to NOSR: I removed relations as the basis for structure(s), regarding them instead only as features of the structure. An important feature of FOSIR is that no abstracta of any kind exist in the ontology to mediate the relation between *I* physical structure and formal structures. FOSIR is anti-Platonist - as a scientific metaphysics. I used IBE/induction, defeasibility, and especially an indispensability argument in conjunction with a scientific metaphysics.

The indispensability of information argument for realism about I-information is not language-centric but contingent-concept centric (concepts adduced by scientists from applied information theory and in scientific research), and I have emphasised the salience of information concepts of various kinds (transmission, codes, encoding, and processing) deployed in theories in physics and molecular biology - especially where such involved a specifically physical structural ontological commitment. As initially discussed at (Intro. §1 p16), it's similar to the Quine-Putnam indispensability argument for realism about mathematical entities (and also to the enhanced IA that takes explanatory power to be important) but, in transitive combination with the inter-supporting but independent argument from inference to the best explanation for CICS and F/OSIR, it delivers an *in re* physical realism about information. I consequently bit the bullet (defeasibly in accordance with scientific metaphysical premises) on a brute identity between the quantum field and vacuum of QFT and the structure of NOSR (OSIR) resulting in a field ontology called field ontic structural informational realism: FOSIR (Chapter 3 and 6.)

I've agreed with Floridi's assertion that no unifying conception or constructive definition - no 'ur-concept' of information - is likely to be possible at the level of mathematical models and representing formalisms (including unifying formal measures) in different theories either practically or in principle. FOSIR with CICS underdetermines all such models and measures, but is intended to identify a necessary condition for all of them to be of or about information.

In fact it requires the omission of statistical constructs from the definition and conception of information and information realisation, with the possible exception of probabilities considered as physical and stochasticity considered as an ineliminable property of dynamical systems or stochastic processes.

FOSIR with CICS does identify an objective, contingent, necessary ontic reductive basis for information and the realisation of information (IS1 and IS2.) It can be identified as the reductive basis of information in all of the abovementioned conceptions of information. Identifying the kind of structure that's ineliminable and present in the ontology of all quantitative and algorithmic conceptions of information is necessary to determine the nature of the ontological basis (or ground, if one insists) of information.

I argued that information encoding representing structures don't encode all of the content of the phenomena/dynamical process(es)/microsystem(s) under investigation, and agreed with French and Van Fraasen there's a partial isomorphism between formal representing structures and the I-obtaining structure. In FOSIR, however, the latter is encoded variously from the former. Thus the answer to the question of what the I structure actually reduces to, is that it is - defeasibly - classical fields reducing to nonuniform heterogeneous regions of the quantum field. Until science comes up with and experimentally verifies or confirms something better. In Chapter's 2 and 3 I rejected mathematising ontologies like that of Tegmark, and modal interpretations of physicalist or scientific metaphysical NOSR such as those of French and Esfeld. I rejected also the objective statistical conception of L&R according to which the ground of the ontology is irreducible stochasticity and thus statistics (the relationship or identity between which I also questioned.) I bit the bullet about real structure as being identical to and/or reducible to nonuniform heterogeneous regions of the universal quantum field - defeasibly. In chapter 3 I went on to assert that I-obtaining stochastic sources are the basis of the ontology - not their stochasticity nor somehow statistics.

OSIR and FOSIR avoid the positing of abstract analytic constructs and various metaphysical 'glues' and intermediates abstracta like trope bundles and property bundles (or the Kantian reification of structure that Cao mentions above), and such things as *infons* They also deflect mathematisation of the I world, and what I have termed formalism driven ontic collapse. The outcome is that informational or information-bearing structure does not depend upon relations, or mathematical relations or constructs. I suggested that the former are features that can be picked out of I-obtaining structure by way of an encoding process involving mathematics, computation, minds, and instruments. The latter are abstract representations of complexes of heterogeneous I-obtaining and non$I$-obtaining structures which themselves reduces to complexes of CICS structures coupled with or governed by nomic constraints (and in some cases constructed rules - which also CICS-reduce.)

Important non-a-priori metaphysical results include the informational restatement of physicalism, which is comprised of the following.

A general metaphysical scientific contingent permitted statement of the ontic basis of information:

> IS1 (Informational Structuralism 1) : Information is (reduces to and is identical to) the causally induced configuration/arrangement of any spatiotemporal structure, the configuration or arrangement of which has been caused or causally induced by some other causal spatiotemporal structure(s.) (CICS information hereafter.)
>
> IS2 (Informational Structuralism 2) : I structure(s) reduce(s), on a defeasible basis, to nonuniform heterogeneous regions of the I-obtaining quantum field.

and an informational statement of the necessary condition for structure to be real:

> SIE (Structural-Informational Eleatic Principal): Structures are to be counted as real if and only if they realise (CICS) information.

This was then further developed to produce:

> EI (eleatic Information Principal or no Pseudo-information principle): Information is to be counted as real if and only if it is realised by causally active physical spatiotemporal structures (configured bounded heterogeneous regions of the quantum field) in accordance with FOSIR.

and finally:

1. $\forall x(Ix)$ (Premise: All existing structures realise (and can and do carry) information)
2. $\forall x(Ix \rightarrow Px)$ (Scientifically supported Hypothesis: Hyp): Only physical structures can realise and carry information)
3. $\forall x(Px)$(1,2 MP: Only physical structures and structures that reduce to physical structures are real.)

I combined the informationist version of NOSR that I developed with these findings and with formalisms in classical and scientific information theory and its applications to deliver the following as a basis for the I-obtaining ontology:

> **OSIR.1**: The world (the set of real things/stuff) is the set of all stochastic, dynamical (reducing to the ephemeral energetic excitations in the combined quantum field and vacuum) CICS information sources.

In Chapter 5 I argued that FOSIR-CICS information is intrinsically semantic but non-alethic. It's a truthmaker, not a truthbearer. I noted that several philosophers have answered the apparent need for a theory of semantic information by offering various theories of semantic information. According to Carnap and Bar-Hillel's offering the semantic information content of a sentence as given by the range of the negation of the formal state description that gives the content of the sentence. Luciano Floridi used the situation theoretic logic of Keith Devlin in combination with an adaptation of the general definition of information to deliver a data centric and atomistic conception of semantic information. Floridi's strongly semantic information is comprised of information atoms or items of information called infons that are in turn comprised of data that must be well formed according to some syntax, be truthful according to a veridicality thesis, and be meaningful. Fred Dretske presents a theory in which semantic information content reduces to intentionality of a signal towards the source that produced it, plus a k-factor constituting what a reciever knows about a source. I carried through arguments that these conceptions are either wrong ontologically, or else they can be shown to reduce to CICS-FOSIR.

The argument makes reference to Carnap and Bar-Hillel's conception of semantic information, and to the later revisionary theory of Floridi (Floridi, 2004a; Floridi, 2005a; Floridi, 2011b) The argument runs that only if one has some information does one have truth, and that there is no such thing as false information - only what looks like real information encoded into messages that are not causally linked with any real *mind, language and representation independent* information source or sources. This I refer to as pseudo-information, following the terminology of Floridi (Floridi, 2005a) and the conception of Dretske (Dretske, 1981.) Dretske asserts that "false information and misinformation are not kinds of information - any more than decoy ducks and rubber ducks are real ducks" (Dretske, 1981, 45.) However, I go still further than both Dretske and Floridi, since each theorist considers that information has an alethic value: it is always true. I remove the concept of truth from information altogether, and take information - per FOSIR and CICS - to be a special kind of truth-maker - not a truth-bearer I argue that a representation of information from or at some source - a representation realised using other information - is a true representation if there is a causally induced structural isomorphism between the source structure (S) and the structure of (constituting, encapsulating, or embodying) the representation $*_i^\rho S$.

There are scientific information-theoretic criteria for the identification of natural I-obtaining dynamical systems as information sources. The I CICS in re physical realist about information has a scientifically coherent, contingent, and defeasible story, based upon the combination of inference to the best explanation with indispensability arguments (§1 p16), about how all real structures realise information, and only physical structures are demonstrably information bearing (§4.4 p162.) More importantly - the story is based upon the fact that when mathematical collapse and formalism driven ontological descent are avoided in formulating metaphysics from particle physics and cosmology: physical transmission, signals, natural encoding, and generation of sequences of emissions or signals with variously effective structures all (contingently) seem to I exist in the systems in question just as much as structure does. In fact the presence of the kind of I-existing structure that is proposed in physics is a sufficient condition for the I existence of signals, emissions, information transmission, and natural encoding by transduction and inducement of configuration. Reduction of signal transmission to continuous transmission of fluctuations in regions of the quantum field is defeasibly a perfectly eligible contingent option for the I basis for information transmission. Quantitative statistical measures of information reduce to measures of stochastic patterns that emerge in such systems due to nomic constraints in the I-existing systems that are the subject of scientific study in physics and biology (and other hard and special sciences.)

So the outcome of approaching the metaphysics of information according to OSIR plus QFT is an informational universe - but information is only at bottom by dint of being an intrinsic feature of nonuniform regions of heterogeneous fields (defeasibly.) I assume that when scientists talk about mind, theory, and language independent structures of physical systems they are talking generally about something that is very real in the ontology, but quite ubiquitous and with different physical contexts. The structure of a physical system is an ineliminable part of the physical system and its ontology. I've argued that such structure is itself physical and that it should not be inflated with metaphysical quasi-logical concreta-cum-abstracta (they are in fact ontologically ambiguous, rather than defeasible) like tropes and bundles - or even relations - but directly explained and described as reducing to fields. Fields are specific natural kind entities in the I physical ontology of the world regarded on scientific realist terms and are contingent in empirical scientific theories. Relations, objects, and information all reduce to structure, but information is something more: it is the causally induced configuration of structures that thus exist and thus reduce, or else reduces to such. Such must really exist in the I ontology, otherwise signal transmission would be - contingently - impossible.

I've to establish a reductionist ontology on scientific metaphysical premises with regard to the existence of information, but for that to be defeasible in terms of the reductive base. If fields stop being the best physical explanation for, and ontological furniture of, quantum structure - supplanted by strings or some modal reality - then the nature of information at bottom will have been revised, but its status as the causally induced configuration of structure retained (unless the latter is unworkable in the light of a change to the former.)

I have not discussed the philosophy of religion at all, but belief in the existence of supernatural entities tells us one thing very salient about the nature of information. Even if a supernatural entity is a fiction (in the cases where they are such) the belief and associated concepts reduce to structures that are physically causally induced. Someone has to think up and write down a fiction at some point, and although I have classified such as pseudo-informational and constituted by virtual sources: neurological physical processing of physical information is required to sustain such fictions (this is quite familiar from traditional identity theoretic and epiphenomenal explanations of mind.) I have provided a conception of intrinsically semantic causally induced information that explains how the semantic content of such pseudo-sources obtains, but the most salient outcome that I hope I have demonstrated is that even fictions that are in some cases thought to be Platonic must reduce to physical information sources at some level - or else they will simply not involve any information at all.

Part V

Appendices

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