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CREATIVITY IN THE ARTS AND SCIENCE

CRIATIVIDADE NAS ARTES E NA CIÊNCIA

CREATIVIDAD EN LAS ARTES Y LA CINENCIA

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Abstract: Only a very rash person would attempt to define creativity in either the arts or science, let alone in both. There is no known recipe for creativity, no magic formula that opens the sluices of originality and guarantees a steady flow of new ideas and fresh insights. Indeed, we do not even know whether creativity is all kind and whether it can be meaningfully discussed under one general category. All we can legitimately do is describe creativity as it is manifested in various fields of human endeavour, from the creation of a beautiful poem to the invention of a new scientific theory. We tackle this problem in the first part of this article; in the second, we take a closer look at artistic and literary representation of science in Europe from the Renaissance to the Romanticism, and, in the third part, we examine the current situation.
Keywords: Creativity; Arts; Science.

Resumo: Somente uma pessoa muito precipitada tentaria definir a criatividade nas artes ou nas ciências, quanto mais em ambas. Não há receita conhecida para a criatividade, nenhuma fórmula mágica que abra as comportas da originalidade e garanta um fluxo constante de novas ideias e novas percepções. Na verdade, nem mesmo sabemos se a criatividade é totalmente de um tipo e se pode ser discutida de forma significativa em uma categoria geral. Tudo o que podemos fazer legitimamente é descrever a criatividade conforme ela se manifesta em vários campos da atividade humana, desde a criação de um belo poema até a invenção de uma nova teoria científica. Abordamos esse problema na primeira parte deste artigo; na segunda parte, examinamos mais de perto a representação artística e literária da ciência na Europa desde o Renascimento até o Romantismo e, na terceira parte, examinamos o estado atual das coisas.
Palavras-chave: Criatividade; Artes; Ciência.

Resumen: Solo una persona muy temeraria trataría de definir la creatividad en las artes o las ciencias, o en ambas. No existe una receta conocida para la creatividad, ninguna fórmula mágica que abra las compuertas de la originalidad y asegure un flujo constante de nuevas ideas y nuevas percepciones. De hecho, ni siquiera sabemos si la creatividad es completamente de un tipo y si se puede discutir de manera significativa en una categoría general. Todo lo que podemos hacer legítimamente es describir la creatividad tal como se manifiesta en varios campos de la actividad humana, desde la creación de un hermoso poema hasta la invención de una nueva teoría científica. Abordamos este problema en la primera parte de este artículo; en la segunda parte, examinamos la representación artística y literaria de la ciencia en Europa desde el Renacimiento hasta lo Romanticismo, y en la tercera parte, examinamos la situación actual.

Palabras clave: Creatividad; Arte; Ciencias.

1 PART I: CREATIVITY

Creativity in the sciences is associated with simplicity, beauty and elegance. It would seem, in short, to be a quality that is best described in the language familiar to the arts, and in attempts such as those made to explain the emergence of a poetical utterance. In his *A Course in Poetics*, Valery muses on the mysterious and yet imperious urge to write poetry:

> Everything I have said so far can be summed up in these few words: a work of the mind exists only in action. Outside of its action nothing is left but an object that presents no relation to the mind. Transport a statue you admire to a country sufficiently different from ours, and it turns into a meaningless stone; a Parthenon into nothing more than a small marble quarry. And when a piece of poetry is used as a collection of grammatical difficulties or illustrations of rules, it ceases immediately to be a work of the mind, since the use that is made of it is utterly alien to the conditions under which it came into being, while at the same time it is denied the consumption value that gives it meaning (VALERY, 1964, p. 100).

A poem on paper is nothing but a piece of writing subject to all the uses to which such writing can be put. But among all its possibilities there is one, and only one, that creates the conditions under which it will take on the force and form of action. A poem is a discourse that demands and induces a continuous connection between the voice that is and the voice that is coming and must come. And this voice must be such as to command a hearing, and call forth an emotional state of which the text is the sole verbal expression. Take away the voice – the right voice – and the whole thing becomes arbitrary. The poem becomes a sequence of signs, connected only in the sense that they are traced one after the other. In a less academic tone of voice, A.E. Housman gives a more personal account of the creative process:

> Having drunk a pint of beer at luncheon – beer is a sedative to the brain, and my afternoons are the least intellectual portion of my life – I would go out for a walk of two or three hours. As I went along, thinking of nothing, only looking at things around me and following the progress of the seasons, there would flow into my mind, with sudden and unaccountable emotion, sometimes a line or two of verse, sometimes a whole stanza at once, accompanied, not preceded, by a vague notion of the poem which they were destined to form part of. Then there would usually be a lull of an hour or so, then perhaps the spring would bubble up again. I say bubble up, because so far as I could make out, the source of the suggestions thus proffered to the brain was an abyss which I have already had occasion to mention, the pit of the stomach. When I got home I wrote them down, leaving gaps, and hoping that further inspiration might be forthcoming another day. Sometimes it was, if I took my walks in a receptive and expectant frame of mind; but sometimes the poem had to be taken in hand and completed by the brain, which was apt to be a matter of trouble and anxiety, involving trial and disappointment, and sometimes ending in failure. I happen to remember distinctly the genesis of the piece which stands last in my first volume. Two of the stanzas, I do not say which, came into my head, just as they are printed, while I was crossing the corner of Hampstead Heath between the Spaniard's Inn and the footpath to Temple Fortune. A third stanza came with a little coaxing after tea. One more was needed, but it did not come: I had to turn to and compose it myself, and that was a laborious business. I wrote it thirteen times, and it was more than a twelvemonth before I got it right (HOUSMAN, 1961, p. 194-195).

An original thinker gets his facts straight or, rather, he straightens out the facts to show how they can be fitted into a coherent whole. The order that rescues facts from their apparently arbitrary occurrence is a creation of the human mind. Be- fore Newton, the fall of an apple and the motion of the moon were disparate events. With the advent of the theory of gravitation, they were recognized as obeying the same laws, and belonging to the same class of phenomena. Likewise, electricity and magnetism were unrelated until Maxwell brought them (and light as well) under his newly invented category of electromagnetic waves. Facts are gathered under the guidance of some organizing principle. The collection of data is a discriminating activity, like the picking of flowers, and unlike the action of a lawnmower. What flowers are chosen and how they are arranged in a bouquet is ultimately a matter of taste, but a taste that is informed by a method, however tacit. Even a machine cannot order facts without being told how to classify them, be it in as simple and straightforward a way as following the letters of the alphabet. Facts only speak when interrogated, and they always reply in the language in which they are spoken to.

The art of memory and the mnemotechnics, which were so popular in the Middle Ages and the Renaissance, are related to efforts to master creativity. They rested on the invention of ways of relating sequences of images to series of concepts. These strategies worked for persons who had a sufficiently vivid imagination to construct a spatial network that could accommodate abstracts ideas, but the phenomenal retention of words, catalogues, even entire encyclopedias was usually more monstrous than creative. Several instances of feats of memory, not unlike ease in making sums or products, turned out to be associated with very modest I.Q.s, and sometimes with glaring intellectual deficiencies. We can be crushed by the burden of data or locked into too rigid a way of organizing them. The information that we glean from the world is of little use unless it can be made to fit a pattern. In an often-quoted passage, Sir Lawrence Bragg, the only physicist to have shared a Nobel Prize with his father for their joint work on analyzing crystals with x-rays, remarks that the essence of science "lies not in discovering facts, but in discovering new ways of thinking about them".

Facts are reticent to come forward, to step onto the scene unless solicited by theory. The German astronomer, Johann Galle, would never have observed the planet Neptune if Urbain Le Verrier had not told him where to look for a body that the Newtonian theory of the gravitation claimed had to be there to account for anomalies in the path of the planet Uranus. Creativity is always a leap, but it is seldom a leap in the dark. It is usually a well-measured jump into a bright patch that is illuminated by theory. The telescope may be the supreme factfinder, but the Copernican revolution was made before, not after, the telescope was invented. The Polish astronomer did not stop the sun in its course and launch the earth into space because he made new observations, but because he felt that the old facts made more sense and, hence, be- came new facts, in the light of his hypothesis. The theory itself was advocated on the grounds that it provided a more "elegant" or "beautiful" framework for the available data. Likewise, Harvey's profoundly revolutionary discovery of the circulation of the blood was made before the invention of the microscope. Harvey was emboldened to conjecture that the blood passes from the arteries to the veins through invisible capillaries because he believed that natural phenomena are largely cyclical, and that perfect and enduring motions are circular. It was only some fifty years after he published his theory that the capillaries were observed by Malpighi. By that time, Harvey's theory was solidly entrenched in medical textbooks.

Einstein's special theory of relativity, published in 1905, did not rest on new data, although it is often assumed that it was devised to explain the outcome of an experiment carried out in 1887 by the American scientists Michelson and Morley, who measured the speed of light and found that it was the same whether light travelled in the direction of the earth or in the opposite direction. Einstein had been wrestling with the paradoxes of current electromagnetic theory, and "harmonizing" them before he heard of the Michelson-Morley experiment. His brilliant assumption, that the speed of light is constant, and that simultaneity is relative, produced such marvelous results that when further and more sophisticated experiments showed in 1925 that the speed of light was not constant, little attention was paid to them be- yond saying that the evidence was almost certainly wrong.

One of the greatest physicists of the twentieth century, Paul Dirac, was fond of emphasizing that new facts alone neither make nor destroy a theory. Commenting upon Schrödinger's famous wave equation of the electron, he wrote: "Schrödinger got his equation by pure thought, looking for some beautiful generalization not by keeping close to the experimental developments on the subject". The Cambridge historian, Herbert Butterfield, makes the same point at the beginning of his influential book, *The Origins of Modern Science* 1300-1800:

> We shall find that in both celestial and terrestrial physics – which hold the strategic place in the whole – change is brought about, not by new observations or additional evidence in the first instance, but by transpositions that were taking place inside the minds of the scientists themselves. Of all forms of mental activity, the most difficult to induce even in the minds of the young, who may be presumed not to have lost their flexibility, is the art of handling the same bundle of data as before but placing them in a new system of relations with one another by giving them a different framework, all of which virtually means putting on a different kind of thinking-cap for the moment. It is easy to teach anybody a new fact about Richelieu, but it needs light from heaven to enable a teacher to break the old framework in which the student has been accustomed to seeing his Richelieu (BUTTERFIELD, 1968, p. 1-2).

The lesson from all this is drawn, in a modern context, by Dirac:

> I think there is a moral to this story, namely that it is more important to have beauty in one's equations than to have them fit experiment. If Schrödinger had been more confident of his work, he could have published it some months earlier, and he could have published a more accurate equation. It seems that if one is working from the point of view of getting beauty in one's equations, and if one has really a sound insight, one is on a sure line of progress. If there is not complete agreement between the results of one's work and experiment, one should not allow oneself to be too discouraged, because the discrepancy may well be due to minor features that are not properly considered and that will get cleared up with further developments of the theory (DIRAC, 1963, p. 43).

Mathematicians use analogous language. "The mathematician's patterns, like the painter's or the poet's, must be beautiful, the ideas, like the colors of the works, must fit together in a harmonious way. Beauty is the first test, there is no permanent place in the world for ugly mathematics", wrote G. H. Hardy in his classic, *A Mathematician's Apology*[1].

2 PART II: ARTISTIC AND LITERARY REPRESENTATION OF SCIENCE IN EUROPE FROM THE RENAIS- SANCE TO THE AGE OF ROMANTICISM

European civilization can be characterized by its Greco-Roman heritage, its Judeo-Christian tradition and, finally, its scientific outlook, which has become the hallmark of all industrialized societies. Indeed, of all the products that Europe exported to the rest of the world, the scientific method is the most prized and the most popular. Whereas Western democracy has met with only a qualified success, Western science has become part and parcel of the way of thinking and, increasingly, of the way of life of every nation on earth.

Science, as we know it, plunges its roots in the remote past and is the fruit of the rational breakthrough that occurred in Ancient Greece and gave rise to our explanation of physical events in naturalistic rather than animistic, symbolic, or religious terms. Around the seventeenth

[1] G. H. Hardy, A Mathematician's Apology. Cambridge: Cambridge University Press, 1967, p. 85.

century, this interpretation of nature took a bold leap forward in what has come to be called the Scientific Revolution, a movement that rapidly spread throughout Europe and helped to fashion our contemporary worldview, not only in laboratories but in society at large. Some of the artistic and literary representations of this new science during the period that runs roughly from the Renaissance to the Age of Romanticism will help us understand the historical genesis of our way of looking at the world. It will also show how art and science are interwoven, and how cultural patterns condition and are, in turn, shaped by scientific developments. If we are to make rational choices about the future, we must be aware of our history, and grasp why science and technology have given rise to great hopes, but also to a feeling of dread and occasional despair.

2.1 THE RENAISSANCE ENGINEERS

A major feature of the scientific method that was developed in Renaissance Europe is the assumption that the universe can be understood on the analogy of a machine. This was rendered possible by the mathematization of the conceptual tools used to interpret nature, but mathematics alone would not have sufficed. Arithmetic and geometry enhanced the understanding of machines as sources of power; they did not create them. From the Middle Ages onwards, technology made steady if unspectacular progress and acquainted an ever-increasing number of people with the benefits of machines, thereby creating the intellectual climate for the mechanization of the world-picture.

The first complex machine to become a public attraction was the mechanical clock. By the fourteenth century, it had become quite common and was often a matter of civic pride. The most famous was built in Strasbourg in 1354 and featured a cock that stretched its neck, flapped its wings, and crowed. Around 1480 spring-driven clocks were introduced, and before the end of the century portable versions - too large to be classed as watches today - were available. Clock-making demanded great accuracy of workmanship and set new standards of precision. When allied to the skill of the millwrights and the builders of other power-driven machinery it opened the door to a new technological age.

The growing interest in machinery is illustrated in the writings and the splendid illustrations of Renaissance engineers such as Leonardo da Vinci (1452-1519) and Francesco di Giorgio Martini (1439-1501). By the time Montaigne went on an extended tour of Switzerland, Southern Germany, and Italy in 1580-1581, it had become fashionable to be on the lookout for technological innovations, especially if they had entertainment value. In his *Journal de voyage*, Montaigne notes practical devices for hoisting and distributing water, and he particularly admired the fine display of fountains and waterfalls at the *Villa d'Este in Tivoli*. He comments enthusiastically on the hydraulic organs that played music to the accompaniment of the fall of water, and devices that imitated the sound of trumpets. He relates how birds began to sing and how, when an owl appeared on a rock, the birdsong ceased abruptly. The rest of Europe sought to emulate Italian achievements, and the King of France, Henri IV, borrowed from Ferdinand I, the Granduke of Tuscany (1551-1609), the services of Tommaso Francini and his brother, Alessandro, to design the waterworks at Saint-Germain-en-Laye. Their creations were to inspire Descartes, who either saw them personally or read about them in Salomon de Caus' *illustrated La raison des forces mouvantes avec diverses machines tant utiles que plaisante saus quel lessont adjoints plusieurs desseings de grotes et fontaines* (Frankfurt, 1615).

2.2 THE SIGNIFICANCE OF MINING

The positive valuation of crafts was reinforced in the writings of several sixteenth-century authors on mining, on mechanics and on machines. The Sienese Vannoccio Biringuccio (1480-ca. 1538) wrote a treatise, Pirotechnia, on ores, assaying, and smelting that is remarkable for its freshness and self-confidence. Biringuccio stressed the openness of scientific knowledge and denounced the secret operations of alchemy as an impediment to progress. He emphasized the accurate crediting of authorship as a form of honesty, and he derided alchemists who concealed their ignorance behind a smokescreen of citations.

Georges Bauer, a physician working in the mining regions of South Germany, and known by the Latinized form of his name, Agricola, discussed various aspects of the extraction and preparation of metals in *De re metallica*, published in Basel in 1556. The sixth book, which deals with machines used in mines for pumping out water, ventilating the shafts and hauling up the ore, is the most lavishly illustrated section of the whole work. It caught the attention of the readers more than other parts that deal more strictly with the nature of the various metals and how they are to be worked. Biringuccio and Agricola were instrumental in changing a prevalent attitude towards mining and, hence, towards nature itself. Because the earth was considered a living being in Antiquity, the formation of metals was the result of a long gestation in womblike matrices deep below the surface. This idea carried ethical im- plications for mining. In his *Natural History*, Pliny (23-79) warned against invading the womb of mother earth, and conjectured that earthquakes were her way of expressing her indignation at this violation. Ovid and Seneca also lamented the greed that made men pry into the bosom of the earth, a theme that is echoed in the two greatest epic poems in english: Edmund Spencer’s Faerie *Queene* (1595) and John Milton’s *Paradise Lost* (1667). Spencer laments the day when mining began:

> Then ‘gan a cursed hand the quiet wombe
> Of his great Grandmother with steele to wound, And the hid treasures in her sacred tombe
> With Sacrilege to dig . . . (Book II, Canto VIII)

Milton describes “bands of pioneers with spade and pickaxe” who, led by Mammon,

> Ransacked the Center, and with impious hands
> Rifled the bowels of their mother Earth
> For Treasures better hid. Soon had his crew
> Opened into the Hill a spacious wound
> And diged out ribbs of Gold . . . (Book I)

Biringuccio and Agricola defended mining against these structures. They argued that minerals and metals were blessings from heaven and that those who did not avail themselves of them wronged themselves and their fatherland. Just as a man catches fish out of the deep blue sea, so he hauls up bounty from the deepest recesses of the Earth. Biringuccio and Agricola did not make a frontal attack on the metaphor of the Earth as a nurturing mother, but their vindication of mining and their praise of machinery contributed to the demise of the organic model and prepared the rise of the mechanistic image that replaced it.

These technological developments provided an environment where natural philosophers had their attention directed to processes of artisans that they might otherwise have overlooked. Renaissance books on machines played a major role in this respect, especially Jacques Besson’s Théâtre des instruments mathématiques et méchaniques (Lyon, 1578), Vittorio Zonca’s Novo teatro di machine et edificij (Padua, 1607), and Agostino Ramelli’sLe diverse et artificiose machine, which was published in a bilingual Italian-French edition in Paris in 1588. Besson’s book has 60 plates, Ramelli’s contains nearly 200 of exceptional quality. All these works are devoted to a wide public conscious of the benefits that better machinery could give them, and they are, especially Ramelli's, aesthetically attractive. Although the engineer's workshop was new territory for most of the illustrators, they rose to the challenge and produced drawings that are both pleasing to the eye and accurate in the rendering of technical details. The importance of illustrations in conveying a precise idea of the nature and functions of the parts of a machine is obvious, and it is surprising that these three great books should have appeared so late. The delay in publishing sketches of mechanical inventions may have something to do with a world that knew little of patents or copyrights, and in which inventors had no interest in publicizing their work for others to plagiarize.

Closely related to the growing interest in machines was the fascination with automata based or developed from models found in antiquity. When the Emperor Charles V abdicated in 1555 and retired to the convent of San Yuste, he was accompanied by a staff of retainers among whom was Gianello Torriano of Cremona (ca. 1515-1585), who distracted the monarch with mechanical figures that simulated living human beings playing musical instruments, such as the lute. In Antiquity, the singing birds of Philo and Hero were motivated by compressed air or steam. An important innovation of the sixteenth century that made possible the reproduction of sound within a self-contained unit was the revolving pinned barrel or cylinder. The action of pins or pegs attached to the circumference of the cylinder or barrel could be transmitted some distance by means of simple levers as the cylinder revolved. If these levers were placed in contact with valves of organ pipes, the pipes would sound for as long as the pins continued to contact the levers. The device made possible the completely mechanical performance of automatic sounding instruments. One of the earliest applications of this invention was made in an organ clock and presented as a gift from Queen Elizabeth to the Sultan of Turkey in 1599.

2.3 HEAVENLY MACHINERY

An unexpected triumph of instrumentation was the telescope which Galileo had the brilliant idea of pointing to the skies where he saw, among other novelties, mountains on the Moon, satellites around Jupiter, and hosts of new stars. Writers greeted this sensational news with a veritable flood of epigrams, eulogies, and encomia. Artists did not wish to be left out, and one of the most famous Italian painters of his day, Lodovico Cardi, known as Cigoli, decorated the vault of the Borghese Chapel in the Roman Church of Santa Maria Maggiore with a drawing of the Moon showing its mountains and craters[2].

Galileo himself wrote one of the first modern books of science that is a literary masterpiece. His *Dialogue on the Two Chief World Systems* is cast in the form of a lively discussion between a witty Copernican, a pedantic Aristotelian, and an allegedly independent observer who is half-converted to the new science. Never had any critic of Aristotle been so gifted as a writer, so apt at convincing an opponent by the sheer brilliance of his presentation, and so masterful at laughing him off the stage when he refused to be persuaded. Galileo drew from the literary resources of his native Italian to convey insights and to stimulate reflection, but his style does not possess the bare factualness of the modern laboratory report or the unflinching rigor of a mathematical deduction. Words are more than vehicles of pure thought. They are sensible entities, and they possess associations with images, memories, and feelings. Galileo knew how to use these associations to attract, hold and absorb attention. He did not present his ideas in the nakedness of abstract thought, but clothed them in the colors of feeling, intending not only to inform and to teach, but to move and to entice to action. He wished to bring about nothing less than a reversal of the 1616 decision banning Copernicanism, and the dialogue form seemed to him most conducive to this end. It is true that the written dialogue is deprived of the eloquence of facial expression and the emphasis of gestures, of the support of modulated tone and changing volume, but it retains the effectiveness of pauses, the

2 See Marcos Cesar Danhoni Neves and Josie Agatha Parrilha da Silva, "Disturbing the Perspective: The New Post-Copernican Moon of Galileo and Cigoli" (2011).

suggestiveness of questions, and the significance of omissions. Galileo made most of these techniques, and he was imitated a generation later by another great writer, Fontenelle, who published his *Entretienssur la pluralité des mondes* in 1686. Widely acclaimed, this work was reprinted 32 times during the author's lifetime, and translated into spanish, italian, german, dutch, greek and russian. In English it was so popular that five different translations, with numerous reprints, appeared between 1687 and 1929.

If enthusiasm was great, not everyone took it for granted that a glorious new age had been ushered in. For many, like the poet John Donne, the new science was a sign that nature was decaying in its old age. Soon after the publication of Galileo's telescopic discoveries, Donne wrote *An Anatomy of the World: the First Anniversary,* in which he expressed sentiments that were echoed among other poets:

So did the world from the first hour decay,
That evening was the beginning of the day,
And now the Springs and Sommers which we see,
Like sonnes of women after fiftie bee.
And new philosophy calls all in doubt,
The Element of Fire is quite put out;
The Sun is lost and th'earth, and no mans wit Can well direct him where to look for it.
And freely man confess that his world's spent, When in the planets, and the Firmament
They seeke so many new; then see that this
Is crumbled out againe to his Atomies. 'Tis all in peeces, all cohaerence gone; All just supply, and all Relation:
Prince, Subject, Father, Sonne, are things forgot, For every man alone thinks he hath got
To be a Phoenix, and that then can bee
None of that kinde, of which he is, but hee.

What sealed the triumph of the new astronomy was the law of universal gravitation that Newton published in his Principia in 1687. Europe stood aghast at the discovery that the fall of on apple to the ground is governed by the same law that guides the planets in their course. This clearly demanded the Muses. They complied and Alexander Pope was moved to write his most famous epitaph:

Nature and Nature's laws lay hid in night:
God said, Let Newton be! and all was light.

For Lessing in Germany, Newton became the very embodiment of truth:

Die Wahr heitkam zuun sim Glanzher abgeflogen
Und hat in Newton die Mensch heitangezogen.

2.4 CELESTIAL AND TERRESTRIAL GLOBES

The new heavens and the new earth entered the salons and became an even more fashionable topic of polite conversation when geographers began producing globes that were both up-to-date and aesthetically pleasing. The work of the Venetian Vincenzo Coronelli is a case in point. In 1683 he astonished the Court at Versailles by constructing for Louis XIV two enormous globes, one celestial and the other terrestrial, each about 10 meters across. These grand, ornamental, and expensive pieces were repositories of useful data, but they were also meant to flatter the King who could afford them. Coronelli, who had a keen sense of publicity, founded the first geographical society in Western Europe, the Academia degli Argonauti, essentially to ensure a wide distribution of his numerous works, over 138 in 3 decades.

Iraheyday the Academy numbered over 250 members throughout Europe with the Pope, the Emperor, and the king of France at the head of the list. Only the heretical English were conspicuously absent.

Coronelli incorporated recent geographical discoveries in his Atlante Veneto, which extended to 13 folio volumes. He used the recent explorations of the Frenchman La Salle (1640-1687) for his map of the Mississippi, and on those of the Dutch van Diemen (1593-1645) for his description of the South Pacific. The reports of Portuguese missionaries enabled him to publish the first map of the Amazon, and a map of Abyssinia with a surprisingly good description of the Blue Nile rising in Lake Tsana. Coronelli went on to lay the foundations of an even greater project: his *Biblioteca Universale, Sacro-Profana, Antica, Moderna*, which was planned to fill 45 volumes plus 10 additional volumes of plates. In scale and concept, it was a precursor of the *Encyclopédie of Diderot* by a margin of 50 years.

The cost and the manpower required to produce these beautiful volumes could become prohibitive. When Coronelli wanted to publish the illustrated manuscript, La Storia del Mogol, by Niccolao Manucci, a second Marco Polo of the seventeenth century, he was prevented by the Venetian booksellers who claimed that there were not enough engravers in the Republic to do the job. When Coronelli died in 1718, his brother Franciscans, who would rather perish than publish, sold the twelve hundred copper plates that had been used to illustrate his books for scrap. They then wrapped themselves into sleepy anonymity for another 80 years or so until Napoleon threw them out and turned the convent of the Frari into the Archivio di Stato.

2.5 THE GLORIFICATION OF THE ARTS AND CRAFTS

Whereas art in the seventeenth century was mostly intended as a glorification of religion, the state, or the king, in the eighteenth century it began to pay greater attention to the investigation of nature and material reality. Nature is no longer a mere scenery or a convenient setting for something else but a source of interest. The greatness of man is revealed in his interaction with the physical world, and he is praised for his ability to tame the wild forces of nature and harness them to make life easier. There is a shift from the *Wunderkammer*, a collection of curiosities over which man has no power, to the cabinet d'histoire naturelle, the forerunner of our laboratory where nature is put to the test and mastered. Manual work is rehabilitated, and the social position of architects and engineers is on the rise. Technological advance is seen not only as a way of increasing the efficiency of labour but also of removing prejudice and enhancing general happiness. Riding, fencing, and dancing are no longer the only elements of a sound education, and young people are taught something about natural philosophy. This they did in the best conditions with instruments of a quality unheard of in previous generations. One of these laboratories can still be admired in its original setting in the University of Coimbra where the Marquis de Pombal transferred the cabinet of the Royal College for Noblemen that had been created in Lisbon around 1766 for the Italian professor Antonio della Bella. The splendid instruments compare with the best ornamental art of the century. They were designed after the famous models that the Van Musschenbroek family had made for the University of Leyden.

The Académie des Sciences started around 1700 a vast collection of technical plates on the arts and crafts but made no serious attempt at publication until prodded by the success of the first volume of plates of the Encyclopédie, which came out in 1762 and may be considered a watershed in the relations between science and society at large. When Diderot and D'Alembert embarked on their monumental project, they initially saw themselves as translating and improving upon *Chambers' Cyclopaedia*, but the title they chose, *Dictionnaire raisonné des Sciences, des Arts et des Métiers*, is revealing of their emphasis on science in action. In his influential *Le siècle de Louis XIV*, Voltaire hailed the Encyclopédieas the major achievement of the eighteenth century, "the repository of all the sciences and all the arts that have been developed as far as human skill will allow". Published over a twenty-year period beginning in 1751, the *Encyclopédie* ran to 36 volumes including the supplements and 11 volumes of plates, which numbered 2,900 in the folio edition. The huge success was due to a large extent to the number and quality of these plates. Never had science and technology been illustrated with such lavishness. The editors borrowed from *Chambers' Cyclopae*dia and other sources, but much work was original. The scientific accuracy and the high precision of the drawings are among the highlights of the *Encyclopédie*. Although none of the engravers were famous, they entered the spirit of the enterprise and did not limit themselves to a faithful representation of the instruments but showed how they could be used. The plates are usually divided into two parts. The bottom half provides a technical drawing of the tools while the upper part depicts a scene where they are being used. The eye is immediately attracted to these tableaux that illustrate the advances of technology in an aesthetically pleasing context. A striking feature of these picturesque representations is their glorification of manual work. But the mill is too pastoral, the workshop too clean, the craftsmen too young to speak of any attempt at realism. The world of technology is a haven of harmony and concord. Even the condition of miners, one of the harshest of the time, is presented as though free from stress or strain. The mechanical arts have become fine arts.

This seductive quality of technology is also found in paintings of the period. The Belgian Léonard Defrance painted impressive interiors of smelting works, and the Swede Per Hillestrom set up his easel in copper mines. But what they saw, they immediately idealized. Beautifully dressed visitors transform hard work into pure and painless spectacle. A good example of this is offered by the entries in the Encyclopédie that refer to printmaking. The plates showing etchers at work present a dignified, tranquil scene, clean, well-lit, spacious, and orderly. The engravers are deeply engrossed in their task and go about their work with the solemnity of a new kind of priesthood. What is left out is the messiness, the dirt, and the clutter of the workshop. There is no sign of the roughness of the printer's life, and the accent is clearly on quality not quantity.

The *Encyclopédie* did not have an enormous run by modern standards: 2500 copies of the folio, and 8500 of the in-quarto. The wide dissemination of illustrations awaited a new image-producing technology: lithography. This planographic chemical process, in which the image is drawn on stone with a greasy substance called "touch", was invented by Alois Senefelder in Germany at the end of the century but it was only slowly introduced to the rest of Europe. Lithography made it possible for the first time in history to print easily and cheaply large numbers of image from a single stone on which the image was drawn, rather than engraved or etched. As a technical innovation, it made the image a household item. It also enabled politicians and members of guilds, as well as anarchists and would be artists, to plaster the walls of buildings with every form of publicity or propaganda.

2.6 THE ROMANTIC REACTION

The celebratory mood that greeted the new science was rarely broken until the end of the eighteenth century when the poet William Blake consigned the godlike Newton to a circle of hell deeper than any in Dante. The Romantic poets followed suit. In December 1817, a group of writers met in the studio of the painter Benjamin Haydon, who tells us in his diary how Wordsworth. In a strain of humor beyond description, abused me for putting Newton's head into my picture; "A fellow," said he, "who believed nothing unless it was as clear as the three sides of a triangle." And then Keats agreed that he had destroyed all the poetry of the rainbow by reducing it to its prismatic colors. It was impossible to resist him, and we all drank "Newton's health, and confusion to mathematics. Not long after this toast, Keats wrote the familiar lines in *Lamia*:

> Do not all charms fly
> At the mere touch of cold philosophy? There was an awful rainbow once in heaven:
> We know her woof, her texture; she is given
> In the dull catalogue of common things. Philosophy will clip an Angel's wings, Conquer all mysteries by rule and line, Empty the haunted air, and gnomed mine – Unweave a rainbow… (HAYDON *apud* NICOLSON, 1966, p. 1)[3].

The wheel of fortune has come full circle. Worshipped, almost deified by the Augustan poets for his successful explanation of the nature of light, Newton is now damned for destroying its numinous character. But science withstood this onslaught, partly because the image of the scientist as a solitary thinker appealed to the Romantics, but more importantly because science remained intelligible and useful. A note of discomfort had been introduced, however, and it continues to echo to the present day.

The Faustian motif lies just below the surface of European consciousness. With Goethe it becomes pervasive and strikes a note of despondency at the heart of human learning. After the prologue in heaven, Faust introduces himself in these words of despair:

> Habe nun, ach! Philosophie, Juristerei und Medizin, Und leiderauchTheologie Durchausstudiert, mitHeissemBemühn. Da stehich nun, icharmer Tor, Und bin so klugalswiezuvor!
> Heisse Magister, HeisseDoktorgar, Und zieheschonan die zehenJahr Herauf, herab und quer und krumm MeineSchüleran der Naseherum—
> Und sehe, dasswirnichtswissenkonnen! Das will mirschier das Herzverbrennen (SHELLEY, 1979, p. 101)[4].

Faust's realization that his learning is futile does not lead him to a humble appraisal of himself. He feels superior to his colleagues, who still believe that progress lies along the path of reason, and he turns to magic, and eventually makes a pact with the Devil to quench his burning thirst for knowledge and power. The Romantics felt excluded from the spirit of the new science although they could not deny that it benefited mankind. The success of medicine, notably pasteurization and vaccination, ensured that science retained public support. Even the railway (against which Wordsworth railed) contributed to the alleviation of man's woes, not only by making travel faster and more comfortable, but by making people aware that human beings need not starve, and hence that they were morally responsible because they could do something about it. But a dark curtain had descended on many scientific projects where the use of increasingly sophisticated technology meant that the public progressively lost access to what was being done or attempted. Indeed, the nature of the scientist became less and less like the nature of the common man. This development was to worry Einstein, who warned, "I can think of nothing more objectionable than the idea of science [only] for scientists. It is almost as bad as art for the artists, and religion for the priests."

3 PART III: THE CURRENT IMAGE OF SCIENCE

What is the current image of the scientist? Is it akin to that of the apprentice sorcerer who unleashed untold misery upon himself and others by memorizing and using formulas that he did not understand? Is it tinged with the latent fear captured in *Frankenstein*, Mary Shelley's early classic of science fiction? Her monster still lives on our TV screens as the archfiend, and

[3] Benjamin Haydon, Autobiography and Memoirs, quoted in Marjorie Hope Nicolson, Newton Demands the Muse (1966).
4 Translation: "Now I have studied thoroughly and eagerly philosophy, law, medicine, and unfortunately also theology, but here I stand like a fool none the wiser. I bear the title of master and of doctor too, and I have led my pupils around by the nose for ten years seeing that we can know nothing. It is almost burning my heart to ashes".

he is usually called Frankenstein. In the novel, however, Dr. Frankenstein is the scientist who pieces him together from living matter, and the creature has no name. It is not his innate malevolence, but his horrible appearance that causes people, including the person who made him, to flee in terror. It is the scientist's gross ineptitude and lack of responsibility for the work of his own hands that is the real cause of the creature's subsequent antisocial behavior. Confronted with his misdeeds, the creature pleads with Dr. Frankenstein:

> Remember, that I am thy creature; I ought to be thy Adam; but I am rather the fallen angel, whom thou drives from joy for no misdeed. Everywhere I see bliss, from which I alone am irrevocably excluded. I was benevolent and good; misery has made me a fiend. Make me happy, and I shall again be virtuous (SHELLEY, 1979, p. 101).

With this plea, the monster persuades Dr. Frankenstein to return to the lab oratory and make him a helpmate with whom he will retire to the wilderness of South America away from all humans. As Dr. Frankenstein is about to breathe life into the female of the new species, he is arrested by the vision of "a race of devils" that would overrun the earth and subjugate mankind. "Had I a right," he asks, "for my own bene- fit, to inflict this curse upon everlasting generations?" Under the eyes of the monster who watches him through the window, he destroys her. Now all fury is unleashed, but the threat to mankind is averted.

In 1817, the first readers of this gothic tale considered it merely an ingenious method of producing a pleasurable frisson; in 1996, when scientists and their corporate sponsors argue before the courts their rights to patent new life forms (genetically engineered bacteria today, higher forms tomorrow), it has become a cautionary tale. Locating his own contribution along the continuous spectrum of scientific "progress", Sigmund Freud saw his psychological revolution as the third major change in human consciousness, following upon the cosmological revolution of the sixteenth and seventeenth centuries, and the biological revolution of the nineteenth. The Copernican astronomy destroyed the notion that the Earth is at the center of the universe and reduced man's abode "to a tiny speck in a world-system of a magnitude hardly conceivable"; the Darwinian theory robbed him of the privilege of special creation and relegated him to a descendant of the animal kingdom; and, finally, Freud's psychoanalysis informed him that he was not master in his own house, but only dimly aware of what was going on unconsciously in his own mind. The fourth revolution might be the "scientific" news that man is just a machine. We cannot be oblivious to the question of saving our ourselves, for reasons analogous to those invoked in Samuel Butler's novel *Erewhon* (nowhere spelt in reverse) published in 1872:

> Man's very soul is due to the machines; it is a machine-made thing; he thinks as he thinks, and he feels as he feels, through the work that machines have wrought upon him, and their existence is quite as much a sine qua non for his, as his for theirs. This fact precludes us from proposing the complete annihilation of machinery, but surely it indicates that we should destroy as many of them as we can possibly dispense with, lest they should tyrannize over us even more completely (BUTLER, 1923, p. 243).

With *Faust* the literary image of the scientist was given a frightening and fiendish touch. Two centuries years later, literature paints science in the same hue. In *1984*, George Orwell's nightmarish vision of an oncoming reign of terror was dis- cussed almost to the breaking point, but thousands of people continue to buy his novel each year. Aldous Huxley's *Brave New World*, first published in 1932, is still on the reading list of large numbers of European students who probably do not realize that the title is a quotation from *The Tempest*, and is used by the author to contrast Shakespeare's heroic individualism with the complacent gregariousness of the year 600 A. F., i.e. *After Ford* (or, perhaps, *After Freud*).

The grim collectivism of tomorrow is symbolized in the drabness and uniformity of the city in which the novel is set: "A squat grey building of only thirty-four stories. Over the main entrance the words, CENTRAL LONDON HATCHERY AND CONDITIONING CENTRE, and, in a shield, the World State's motto, COMMUNITY, IDENTITY, STABILITY". In this new world natural childbearing has been replaced by artificial child production. Ovaries and sperms still must be delivered by living women and men, but one impregnated egg can be artificially hatched to produce ninety-six identical clones. The development of the fetuses is determined chemically and psychologically, so that individuals are completely predestined socially. Words such as "born" and "parents" are obscenities. The greatest social virtue is stability. To implement this value, the rulers have given top priority to research into methods of eliminating all personal interests. Sexual relations have been shorn of their dramatic and passionate character and trivialized. Drugs are avail- able to prevent the body from going out of control. Children are taught not to fear death by visiting a gigantic terminal clinic with perfumed air-conditioning, TV sets at every bedside, synthetic music all over the place, and hundreds of drugged old people happily expiring.

The novel's dilemma, ether totalitarianism or irrational primitivism, is too stark. But it is an effective way of stressing that technology must be, not the goal to which every person must adapt, but a way of creating free and responsible individuals. *Brave New World's* paradise is based on social engineering, the worship of health and youth, and public control of knowledge. "*His Fordship*", Mustapha Mond, one of the "controllers" of the *World State*, sums up the evolution of science and society since Ford's own day:

> Knowledge was the highest good, truth the supreme value; all the rest was secondary and subordinate. True, ideas were beginning to change even then. Our Ford himself did a great deal to shift the emphasis from truth and beauty to comfort and happiness. Still, in spite of everything, unrestricted scientific research was still permitted. People still went on talking about truth and beauty as thought they were the sovereign goods. Right up to the time of the Nine Years' War people were ready to have even their appetites controlled then. Anything for a quiet life. We have gone on controlling ever since. It has not been very good for truth, of course. But it has been very good for happiness (HUXLEY, 2020, p. 178-179).

When Europe is questioning the role of basic research and urging everyone to turn to applied ("happy") science, does Huxley's vision of a science in bonds comes a bit too close for today's reader? Herein lies our dilemma. The air we breathe is hardly more necessary than the technology on whose strength European civilization is built but too many of our citizens are uncomfortable with science. The problem is compounded because the industrialization of technology has led to the transformation of our daily lives, from fast food to instantaneous telecommunications. Our houses and our offices are full of more and more gadgets that we understand less and less, and our ignorance inhibits our ability to evaluate their real impact and to assess their ethical implications. Blind faith in the benign influence of science and technology has been waning at the very moment when they are encroaching more and more into our daily lives!

Some modern projects are so vast and call for such a variety of expertise's that even the members of the scientific community can no longer embrace all their aspects. How is the funding for these mega-projects to be accounted for in terms that are intelligible to the citizens or their representatives? This at a time when everyone has suddenly become morally accountable: the engineer, who is told that it is not enough to design an efficient plant, as he has been trained to do, but that he must gauge its impact on the environment, for which he has no training whatsoever; the administrator, who is asked to consider the long-range consequences of computerization on his personnel; the manager, who has to assess the social implications of automation in his factory; the doctor, who is faced with new ethical problems posed by a technology that enables him to initiate or prolong life almost at will; the parents, who have to decide what additives are acceptable in the food they give their children; and the banker, who is expected to respect privacy and to safeguard the computerized network from becoming a vehicle for fraud.

To whom or what are people to turn, since science can no longer be called a charismatic profession capable of training men and women to look at nature in an objective and self-detached way? While we wring our hands (at conferences or in the seclusion of our studies), the list of problems grows: more pharmaceuticals are discovered to have dangerous side-effects; the ozone layer is being depleted; our lakes and rivers become more polluted. The arts and the sciences must tackle these problems together. On the threshold of the twenty-first century, European scientists, artists, and writers must learn to communicate and ponder the values and goods that can guide us not only in our quest for better jobs and better health but also towards a better understanding of ourselves and the world we live in.

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