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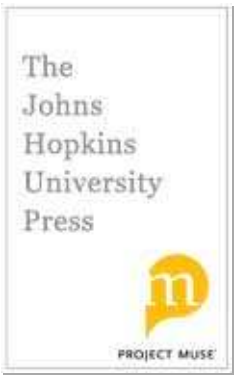

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Jacques Monod, François Jacob, and the Lysenko Affair: Boundary Work

John Marks

THE LYSENKO AFFAIR IS SYNONYMOUS with the ideological distortion of science in the 1930s and 1940s in the USSR. The Ukrainian agronomist Trofim Denisovich Lysenko (1898-1976), supported and endorsed by Stalin, was instrumental in turning Soviet science away from Mendelian genetics. In contrast to the emphasis that genetics placed on the existence of a hereditary substance contained in the chromosome material that is impervious to practically all environmental influences, Lysenko doggedly promoted a neo-Lamarckian model of the inheritance of acquired characteristics. The personal, intellectual, and economic consequences of Lysenko's project were devastating: Soviet genetics was destroyed; geneticists were persecuted, imprisoned, and executed; and Soviet agriculture suffered. In a wider sense Lysenkoism was drawn into the ideological battleground in the Cold War struggle for the hearts and minds of Europe's intellectual elites in the immediate post-war era. The Soviet rejection of genetics stood in contrast to the development of a neo-Darwinist molecular genetics in the West. In France, the official endorsement of Lysenkoism in 1948 gave rise to a proxy *affaire* in the form of a confrontation between those whose allegiance to the Parti communiste français (PCF) led them to defend Lysenko's views and those who denounced what they saw as ideological distortions.[1]

The aim of this article is twofold. First, the broad aim is to provide some context to the particular position of French biology and French scientists within this battleground of ideas. One of the key components of this context is the emergence of molecular biology in the post-war era and the important role that French scientists such as François Jacob and Jacques Monod played in the development of this new area, which seemed to confirm the central tenets of Mendelian genetics. Second, the article will explore how the informational paradigm that Monod and Jacob elaborated in order to understand genetic regulation, which began with a terminological shift from *adaptation* to *induction* in 1953, should be seen in the context of the Lysenko affair. That is not to say that Jacob and Monod set out to construct a scientific model that opposes Lysenkoism, but rather that Lysenkoism provides a stimulus to understand and interpret the science they are doing in a particular way. Reacting against Lysenko's attack on genetics, Jacob and Monod focused their scientific work on the way

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the genetic material could regulate the activity of the cell. At a time when new geopolitical borders and barriers were being constructed, molecular biology claimed to have identified a rigidly policed border between the genetic material in the cell nucleus and the rest of the cell. The idea of the transposition of Cold War border control at the macro level of the Iron Curtain to the molecular level of the cell is captured well by Depew and Weber's interpretation of the consequences of post-war molecular biology for evolutionary theory. The ideological struggle around Lysenkoism rested on a boundary dispute: neo-Darwinist genetics effectively erected a barrier between the germ cells and somatic cells in multicellular organisms. This was a new version of the barrier that the German biologist Auguste Weismann (1834-1914) had proposed in the nineteenth century. The ideological dimensions of the struggle are reinforced by the terminology chosen by Crick and Watson in 1953 to describe the unidirectional flow of information from DNA:

> The picket fence of Weismann's barrier, on which the genetic theory of natural selection was based, was suddenly transformed into the Berlin wall of the central dogma of molecular biology: *Information in biological systems flows unidirectionally from nucleic acid to protein*.[2]

The cartographical and geopolitical metaphors at play here are highly significant. What we see in the Lysenko affair is a particularly complex version of what Thomas F. Gieryn describes as "boundary work."[3] For Gieryn, science within society is continually involved in a process of *mapping*, of rhetorically defining the boundaries between science and non-science. From a sociological point of view, Gieryn is struck by the "variability, changeability, inconsistency, and volatility" of these maps. There are, he claims, few universal or transcendent qualities of science that can be extracted from this mapping activity: "The contours of science are shaped instead by the local contingencies of the moment: the adversaries then and there, the stakes, the geographically challenged audiences" (Gieryn 5). Gieryn concentrates primarily on the construction and consumption of science and scientific legitimacy "downstream," in the broadly social realm, and the Lysenko affair is certainly characterised by such boundary work. However, the aim here will also be to show how crucial work of this kind also takes place "upstream," in the experimental work that biologists undertake in order to define and understand the borders and boundaries within the cell.

Neo-Lamarckism, the politics of inheritance and molecular biology

It is important to recognise that this post-war struggle to define the boundaries and nature of genetic material was carried out in the shadow of

National Socialism's insistence upon a crude form of genetic determinism. Nazi theories of racial hygiene required a rigid separation, in line with Weismann's theory, between germ plasm and somato-plasm. Racial characteristics were seen as deep-rooted and immutable; a 'race' was an expression of a bloodline. Environmental influences could not be integrated into the process of inheritance, and the only way to 'improve' a race was to 'purify' the genetic stock by eugenic means.[4] The notion of the inheritance of acquired characteristics was dismissed as an expression of the socialist belief in the importance of environment and the malleability of human nature. The association of Mendelism and Darwinian natural selection with Nazism undoubtedly bolstered the predominance of a neo-Lamarckian view of heredity in France. The roots of this preference for Lamarck, however, go back into the nineteenth century. Jan Sapp has identified the 1880s as the moment when neo-Lamarckism emerged as a hegemonic discourse in French biology.[5] Darwinism was increasingly identified with theory of natural selection, which was broadly rejected in France. Several commentators have argued that the persistence of Lamarckism meant that French biology was susceptible to the influence of Lysenkoism.[6]

France was not, in short, promising territory for the development of molecular biology, which stood squarely within a Mendelian genetic paradigm. However, the collaborative work of Jacob and Monod in the 1950s eventually led to the concept of gene regulation and the formulation of the operon model, the highpoint of the cybernetic, informational formulation of molecular biology that followed on from Crick and Watson's discovery of the double-helix structure of DNA in 1953. In addition, both Monod and Jacob wrote books in which each attempted to explain the significance of molecular biology to a general audience.[7] In *Le Hasard et la nécessité* (1970) Monod portrays the biochemical machinery of the cell in cybernetic terms, and in *La Logique du vivant* (1970) Jacob also draws on cybernetics to describe inheritance in terms of information transfer. Both Jacob and Monod subscribe to a broadly neo-Darwinist view of evolution as a non-teleological process driven by chance, and of genes as a sort of computer programme, which are incapable of 'learning' from the environment. Their understanding of genes as units of information stood in stark contrast to neo-Lamarckism. The focus on genes as information command and control systems pointed away from notions of acquired characteristics and environmental influences towards a Mendelian, neo-Darwinist gene-centred model of evolutionary development.

Science and democracy

How, then, was it possible for Jacob and Monod to make such an important contribution to molecular biology? At least part of the explanation lies in the intellectual and economic influence of American science, which played a significant role in the general re-orienation and re-energisation of French scientific activity after the Second World War. American science saw itself, and was seen, as embodying values of dynamism, openness and, crucially, objectivity. America would support science that was meritocratic and untainted by ideological concerns. As David A. Hollinger emphasises, this attitude to science can be traced back to the emergence of a strong, secular, broadly leftist understanding of science that begins to emerge in the 1930s in opposition to totalitarian appropriations of science:

> Bland as most of their formulations might seem from afar, to these intellectuals it mattered enormously to be "objective," to look upon factual realities "without prejudice," to "actually test with experience" one's opinions, and to report "honestly" the result of one's inquiries. These men and women saw a world filled with "prejudice" and with efforts to "impose certain opinions by force." Against these evils one must affirm "free inquiry" and "open-mindedness" in order that our society might be organized realistically on the basis of the conditions life actually presents.[8]

The act of seeking to promote and fund scientific work that conformed to these criteria inevitably became part of the cultural Cold War between the United States and its allies and the Soviet Union. Freedom of thought, expression, and disinterested scientific investigation were set against the ideological dogma of Soviet, communist science. The relative electoral success of the French Communist Party in 1946 (five million votes), coupled with the fact that the party had close links with the Soviet authorities, meant that the United States identified France as a key ideological battleground. The U.S. State Department was unequivocal on the matter:

> A New France, a new society is rising up from the ruins of the Occupation; the best of its efforts is magnificent, but the problems are staggering. In France the issue of the conflict or the adaptation between communism and western democracy appears in its most acute form. France is its battlefield or laboratory.[9]

It is important to emphasise that the Communist International promoted a competing view of science in the 1930s. The Party actively sought to attract intellectuals, artists, and scientists in Western Europe, and the emphasis placed on the social utility of science, as well as the assertion that science facilitated progressive technological advancement, struck a chord with many left-leaning scientists in Europe.[10]

Lysenkoism

Opinions differ regarding the extent to which Lysenko's rejection of the 'bourgeois' science of genetics had its roots in Lamarckism, dialectical materialism, or was simply driven by an opportunistic and ruthlessly ambitious drive to take control of Soviet agriculture. However, it is indisputable that the rise of Lysenko and the support he enjoyed from Stalin was paralleled by an official rejection of so-called Mendelist-Morganist genetics, which in turn fed into a biological Cold War. The roots of this conception of genetics lay in debates around neo-Lamarckist theories in the late 1920s and early 1930s in the USSR. This was the first point at which pressure began to be exerted to promote a view of heredity that emphasised the transformative role of environment and the inheritance of acquired characteristics. In the 1930s Stalin insisted upon *theory* in all spheres that would be of service to revolutionary practice. Bourgeois science had to be reconstructed in line with dialectical materialism, and it needed to demonstrate its usefulness for agriculture and medicine.[11] Lysenko took this opportunity to formulate a 'proletarian' biology that conformed to the tenets of dialectical materialism. This was also a particularly brutal phase of Stalinist terror, of which Lysenko took advantage to discredit Nikolai Vavilov, one of the most respected biologists at that time in the USSR (Vavilov was arrested in 1940 and died in prison in 1943).

Lysenko began to emerge as an influential figure in the late 1920s when much was made in the Soviet press of the alleged success of his use of the technique of "vernalisation"—obtaining winter crops from summer planting by soaking and chilling germinated seeds—and he was celebrated as a peasant "barefoot scientist." In the 1930s he developed a theory of the "phasic" development of plants to explain the technique of vernalisation. When Lysenko seized upon the growing interest in the work of Michurin, who believed that environment played a crucial role in heredity, he began to formulate an ideologically motivated attack on genetics and geneticists. Ultimately, he claimed that heredity did not lie in the genes, since there was no germinal line in the form of a self-reproducing substance. Instead, he insisted that environment has a significant effect upon heredity, and also that traits acquired during the lifetime of an organism—by grafts for example—could be passed on to future generations. The idea that genes are protected from environmental influence and are subject to random mutations was seen as being in conflict with the principles of Marxist-Leninist ideology. Lysenko instead promoted his own version of neo-Lamarckism as an expression of dialectical materialism. Mendelian genetics was thought of as a conservative, 'bourgeois' view of nature, whereas Lysenkoism emphasised the mutual influence of organism and

environment. Also, Mendelian genetics was seen as undermining the notion that nature can be transformed by human intervention. As Jan Sapp puts it, Lysenko promoted the notion that nature could be "sculpted at will."[12]

As indicated already, the Soviet debate on biology and the rise of Lysenkoism ultimately had a wider ideological resonance outside of the USSR within the framework of the Cold War. The state-endorsed Soviet view of biological inheritance stood in contrast to an American-led focus on Mendelian genetics, and in the late summer of 1948 Lysenko received official state endorsement at the Lenin Academy of Agricultural Sciences in Moscow. Nikolai Krementsov has argued that it was only at this point, the very inception of the Cold War, that Lysenko finally gained the unequivocal support of Stalin by presenting a clear opposition between two opposing camps in the world of biology which corresponded to the division between the Soviet bloc and the West:

> The essence of Lysenko's address was a juxtaposition of two opposing trends in biology: unscientific, idealist, scholastic, sterile, reactionary, anti-Darwinist Weismannism-Mendelism-Morganism versus scientific, materialist, creative, productive, progressive, Darwinist Michurinist biology. These two sets of antonymic labels obviously reflected the current sociopolitical situation: the escalating situation between the USSR and the West, or, as Lysenko phrased it "two worlds—two ideologies in biology."[13]

It is important to emphasise the shock effect of this stark ideological framing of biology on French scientists and intellectuals. Although from 1936 onwards there were rumours of the difficulties experienced by Soviet geneticists, Communist intellectuals in France continued, throughout the 1930s and into the 1940s, to subscribe to the notion of a philosophical and scientific link between dialectical materialism and neo-Darwinism. As late as 1939, for example, the first issue of the journal *La Pensée*, created by the PCF, had expressed a strong neo-Darwinian consensus (Kotek and Kotek 107-08). However, Lysenko's report to the Lenin Academy in 1948 finally brought home the profoundly ideological character of "Soviet Biology."[14] The initial spark to the *affaire* in France was an article by Jean Champenois that appeared in Communist journal *Les Lettres françaises* in late August 1948. Champenois, the Moscow correspondent of the journal, reported on the session of the Lenin Academy. His report had been approved by the Central Committee of the Soviet Communist Party, and he made no effort to downplay the ideological dimensions of Lysenko's attack on genetics. He hailed the official endorsement that Lysenko has received from the Academy as a "un grand événement scientifique," and as confirmation that heredity "n'est pas commandée par de mystérieux facteurs." Instead of there being a special sub-

stance that is the sole vehicle for heredity, the living organism is defined by all its parts, which constitute a dynamic and interactive unity. Alluding to the Nazis, he claimed that the idea that evolution worked by means of natural selection was essentially a racist form of thinking. Lysenkosim was just one expression of an ideological divide between the progressive socialism of the East and the West's disdain for the productive potential of humanity and nature. Nature could be modified by environmental influences, and these modifications could be passed from generation to generation.

A large number of French intellectuals and scientists, including Monod, were shocked that Lysenko's views should be defended in such brazenly political and ideological terms. The title of Monod's intervention in the newspaper *Combat* showed just how uncompromising his position was: "La Victoire de Lyssenko n'a aucun caractère scientifique." For Monod, it was not a question of political opportunism, but rather of a deeply misguided drive to construct a form of biology that conformed to Soviet doctrine. He emphasised that Lysenko could have persuaded the Soviet authorities of the validity of his theories only because they were ideologically predisposed to accept them:

> Par quels moyens, par quels enchantements, Lyssenko a-t-il pu conduire les plus hautes autorités du régime, les persuader d'assurer son triomphe, acculer ses adversaires à la démission ou à l'abjuration? […] C'est que le fantasme doctrinal, la casuistique stérile d'un Lyssenko correspondaient effectivement à leurs modes de raisonnement, satisfaisaient leur pensée. […] En définitive, ce qui ressort le plus clairement de cette grotesque et lamentable affaire, c'est la mortelle déchéance dans laquelle est tombée en URSS la pensée socialiste.[15]

Monod's dismay was no doubt confirmed by the way the PCF was able to mobilise intellectuals such as Louis Aragon. In his preface to Jaurès Medvedev's *Grandeur et chute de Lyssenko*, published in 1971 in France, Monod stated in even stronger terms the view that the cult of personality and political manoeuvring on the part of Lysenko cannot wholly explain why his theories came to be accepted as Marxist orthodoxy:

> Si Lyssenko s'est imposé, *c'est qu'il a été cru*. Et s'il l'a été, c'est à mon avis, au delà des machinations, des intrigues, des calumnies et des falsifications (sur lesquelles insiste naturellement Medvedev) parce que, dans le ton, dans le style comme dans le fond, ses positions "théoriques" étaient conformes à une certaine tradition idéologique, exaspérée certes par le culte de la personnalité, mais assimilée au "marxisme" et bien antérieure au stalinisme proprement dit.[16]

For Monod then, the so-called "Lysenko affair" was a particularly spectacular example of the way Marxist thought had fallen into disrepute by imposing an ideological framework on reality: dialectical materialism. After the Second

World War, Monod quickly withdrew from the Communist Party, in large part because he felt uncomfortable with the pressure that was exerted to support the party line at all costs. The Lysenko affair only confirmed for Monod the essential dishonesty and frequent absurdity of officially sanctioned ideological positions.

The Lysenko affair also influenced François Jacob's decision to carry out scientific work in the field of genetics.[17] In both *Le Jeu des possibles* (1981) and *La Souris, la mouche et l'homme* (2000) Jacob has returned again to the significance of Lysenkoism as a turning point.[18] He describes theories of heredity that depend upon acquired characteristics and which, in his opinion, fly in the face of the evidence accumulated from genetics and molecular biology as attempts to impose wishful thinking on reality. Any scientist who cheats in this way contravenes the rational and moral rules of science (Jacob, *Le Jeu des possibles* 36). In this respect, the decision to undertake research in genetics was, in part at least, a political act for Jacob: "Faire de la génétique, c'était refuser l'intolérance et le fanatisme" (Jacob, *La Statue* 234).

American influences

As discussed already, the USA actively sought to influence scientific activity in France after the Second World War, and recent research has highlighted the efforts made to resist the perceived threat of Lysenkoism. A key figure in this context was Warren Weaver, who was director of the Natural Sciences Division of the Rockefeller Foundation. In the 1930s Weaver had developed a research programme focused on a "molecular" approach to human biology, drawing on new techniques in physics and chemistry (Krige 77). After the Second World War, Weaver identified France as a territory that urgently required support in the field of science. The Rockefeller Foundation had already established a presence in France, and Weaver was enthusiastic about the possibility of supporting the development of genetics in France, which challenged the predominantly conservative, neo-Lamarckian approach of French biology at the time. In the years after the war, Weaver awarded two major grants to French researchers: a large grant for equipment and international conferences to the CNRS, and a grant awarded to Boris Ephrussi to help set up a new genetics research institute at Gif-sur-Yvette. John Krige is quite clear about Weaver's motives in making these awards. His mission was to use the fairly considerable financial and technological means in his gift to transform at least some French scientists into more outward-looking, internationally orientated researchers (Krige 81).

Both Krige and Jan Sapp have researched extensively the concerns expressed by Weaver and the Rockefeller Foundation regarding the potential

influence of Lysenkoism within the Institute of Genetics at Gif. When Boris Ephrussi applied in July 1949 for a grant of $54,000 to fund equipment at Gif, Weaver responded by asking for an "assurance from the geneticists involved that their scientific work will be uninfluenced by political considerations or party loyalties" (quoted in Sapp, *Beyond the Gene* 183). Of particular concern for Weaver was the fact that key scientists at the Institute—namely Ephrussi himself, Philippe L'Héritier and Georges Teissier—had not made a clear enough stand against Lysenko's neo-Lamarckist position (Krige 129). Krige and Sapp make extensive use of archive material to demonstrate the fairly intense pressure exerted on Ephrussi when he visited New York on a CNRS-funded trip for discussions with Weaver and Pomerat in early 1950. Ephrussi was questioned thoroughly on his own political views. He was asked if he would attempt to force Teissier's resignation if a scientific paper expressing Lysenkoist views were to be published by Gif. Similarly, he was asked if he was willing to demand that all papers by his colleagues be approved by him before publication. Ephrussi refused, but he felt compelled to demonstrate his anti-Lysenkoist credentials (Krige 136). Weaver and Pomerat, influenced by the anti-Communist climate of public life in the USA, had a one-dimensional view of the dangers posed to genetics in France by what Weaver termed "leftist Lysenkoism." For one thing, they did not initially appear to understand that the representatives of the still-powerful tradition of French Lamarckism were in many cases ultra-conservative in political terms. Consequently, they erroneously assumed a straightforward correspondence between Lamarckian and Lysenkoist views and Communist sympathies (Krige 137).

Monod: from adaptation to induction

As far as Weaver's mission to open up French science to American influences was concerned, Jacques Monod had already engaged in transatlantic exchanges. Boris Ephrussi encouraged Monod to spend time at the California Institute of Technology on a Rockefeller grant in the 1930s, and Monod joined T. H. Morgan's group at Cal Tech, where he was introduced to new ideas and new ways of working. Conceptually, Morgan's interest in bringing physics and chemistry into biology was revolutionary, and Monod's later work was strongly influenced by the focus on forging links between genetics and biochemistry. Morgan also had distinctive views on the ways to build a strong research culture, and Monod was struck by the contrast with the formality and rigorous specialisation of intellectual life at the Sorbonne, and the speculative, informal approach to research at Cal Tech. Furthermore he found himself in tune with Morgan's belief that scientific research should be free from utilitarian pressures.

Monod himself subsequently referred to the impact of his time at Cal Tech in his Nobel Prize speech in 1965. The experience was a "revelation" for him, showing just what could be achieved by what he clearly perceived as a democratic and open, but also rigorous, objective, and forensic exchange of ideas:

> Révélation de la génétique, alors presque ignorée en France; révélation de ce que peut être un groupe d'hommes de science en pleine activité créatrice, lorsqu'il associe dans un constant échange d'idées, de spéculations hardies, de critiques serrées, des personnalités de haute stature telles que George Beadle, Sterling Emerson, Bridges, Sturtevant, Jack Schultz, Ephrussi, qui tous alors travaillaient dans le département de Morgan.[19]

Monod returned to France in 1937 and, after a brief period at the Institut de biologie physico-chimique (IBPC), he went back to the Sorbonne, where he began to work on mechanisms of regulation in enzymes. Monod worked in particular on the way enzymes break down the sugar lactose, and, on the advice of André Lwoff, he chose to carry out his experiments with *Escherichi coli*. The first significant result of Monod's experimental work was the discovery of a phenomenon that he labelled "diauxie" (meaning "double growth"). Monod discovered that bacteria grown in some combinations of sugars displayed two distinct growth phases, with an intermediate phase in which little or no growth took place. Lwoff suggested to Monod that the reason for this phenomenon could be "enzymatic adaptation."

Although he was active in the French Resistance, Monod continued his work on enzymes and biometry throughout the Second World War. After the war he came to question the hypothesis of enzymatic adaptation that he had arrived at in discussion with André Lwoff. The Lysenko affair provided a crucial stimulus to a radical change of perspective on Monod's part. He found himself in a curious and somewhat uncomfortable position: he instinctively reacted against what was perceived as the scientific nonsense of Lysenkoism, but the hypothesis of enzymatic adaptation appeared to confirm a Lysenkoist notion of acquired characteristics, since it was premised on cytoplasmic inheritance and environmental influence (Debré 161). Ultimately, Monod adopted the terms "induction" rather than "adaptation," a change in terminology that Monod announced, in the form of a short notice, co-signed by several distinguished collaborators in the journal *Nature* in 1953, roughly six months before the announcement in the same journal of the DNA double helix.[20] Lily E. Kay argues that the significance of this short notice went beyond issues of terminological precision. Monod and his co-authors effectively formalised a paradigm shift in the study of enzyme adaptation that fed into the broader DNA paradigm shift that took place in the early 1950s. The substitution of

"induction" for "adaptation" constituted what Kay calls a "profound gestalt switch" in biology. It stood as a challenge to Lysenkoism, and it set molecular biology on a new, cybernetic path, whereby organisms would be seen as "reservoirs of genetic potentialities, as informational programs impervious to the environment, regulated purely internally and executed through a series of transformations."[21] In this sense, the article in *Nature* announcing a terminological shift to "induction" had the quality, as Kay puts it, of an "ideologically charged scientific encyclical": it was a challenge to teleological notions of evolution and to Lysenkoism (Kay 202). It was, in short, a significant act of boundary work.

PaJaMo

Subsequently, Monod worked in close collaboration with François Jacob, which led to so-called "PaJaMa" ("PaJaMo" in French) experiments carried out by Jacob, Monod, and Arthur Pardee from 1957 onwards. These experiments brought together Monod's work on enzymatic function and Jacob's focus on genes in a new experimental hybrid in order to study the lactose system in bacteria. Initially, they were surprised by the results of the experiments, and it was only when they came up with the idea that there might be a way certain genes exercised a form of control that things began to fall into place. This idea ultimately led them to formulate the so-called "operon" model. This model proposed the existence of two different kinds of genes: structural genes that code for enzymes and structural proteins; and regulatory genes that code for proteins that control the activity or expression of structural genes. The operon model suggested a computer-like role for DNA and RNA, according to which, genes would provide a coordinated programme of protein synthesis. They identified "repressor" and "promoter" proteins and genes that switch other genes on or off. The operon model of enzyme induction hypothesises that, when lactose is absent, the repressor molecule attaches itself to the operator gene, and so switches it off. When lactose is present, on the other hand, the repressor molecule cannot attach itself to the operator gene, so it remains switched on. In other words the structural gene is operational, and codes for beta-galactosidase, which breaks down lactose. The operon hypothesis had two important consequences for molecular biology as a paradigm. First, it indicated that, as Monod had already suggested, it was the DNA in the cell that controlled the reaction to lactose, rather than lactose causing the cell to adapt. Lactose is an inducer, setting in motion a programme that already exists. Jacob describes this discovery in *Le Jeu des possibles* as a significant move away from a Lamarckist, "instructionist" conception of acquired characteristics:

> On a longtemps pensé que le sucre apportait de l'information à la bactérie; qu'il enseignait, pour ainsi dire, à la protéine la forme à prendre pour avoir cette activité enzymatique particulière. Mais lorsque les bactéries sont devenues accessibles à l'analyse génétique, cette hypothèse didactique s'est révélée fausse. Le sucre agit simplement comme un signal pour faire démarrer la synthèse de la protéine, c'est-à-dire mettre en route une série de processus réglés par les gènes jusque dans le détail. Il choisit dans le répertoire génétique et active le gène codant cette protéine. Mais la structure et l'activité de la protéine restent complètement indépendantes du sucre. Le mécanisme est entièrement sélectif. (Jacob, *Le Jeu* 37)

For Jacob, this was, as he puts it in his autobiography, "Encore une victoire de Darwin sur Lamarck!" (Jacob, *La Statue* 302). Jacob and Monod put it in the following way: "The discovery of regulator and operator genes, and of repressive regulation of the activity of structural genes, reveals that the genome contains not only a series of blue-prints, but a co-ordinated program of protein synthesis and the means of controlling its execution."[22]

Conclusion

The aim here has been to look at the way the Lysenko affair influenced the practice and presentation of molecular biology—the boundary work—that took place in defining the role of genes and genetic regulation, as well as the notion of 'objective,' value-free science. In many ways, this boundary work was clearly successful. Molecular biology located and contained command and control functions within the genome. At the same time, it was associated with an open, 'democratic' style of science. The persistence of this view of the Lysenko affair is illustrated by Michel Morange's recent reassertion of the importance of Jacques Monod's scientific legacy as one of the founders of molecular biology, and he attributes a significant role to the Lysenko affair. Morange argues that the affair influenced both Monod's scientific orientation as well as his general commitment to 'objective' science:

> The time and effort spent by Monod to disentangle the arguments of the supporters of Lysenko are quite remarkable. It was not a waste of time for him. It gave him the opportunity to firmly establish the bases of present biological knowledge, and to show that science is not the simple product of the societies in which it is elaborated, but rather the result of a powerful process of objectification, which gives scientific knowledge an incomparable value.[23]

However, the clear and rigid boundaries constructed in this period should perhaps be considered in retrospect more as rhetorical strategies of containment than as scientific truths. It may even be the case that protagonists like Monod and Jacob were more ambivalent about these boundaries than they realised. Richard Doyle draws out this ambivalence by means of an elegant

deconstructive reading of the rhetoric of gene 'control' in the work of Jacob and Monod.[24] Doyle argues that Jacob and Monod's rhetorical strategy in "Genetic Regulatory Mechanisms in the Synthesis of Proteins" allows them to seal the genome off from external agency, whilst at the same time incorporating this agency into the genome: they collapse together a rhetoric of "instruction" and "construction." The complexity of gene expression is reduced to, and shown to be contained in, the genome. In this way, Doyle argues, Jacob and Monod constuct a "nucleic acid world," in which life is located in DNA and not in bodies. In their rhetoric, the "genome" becomes a synecdoche: it is one site in the complex spatial and temporal process of gene expression within the cell, but it comes to stand for the entire process (Doyle 72). The effect of these rhetorical sleights of hand is to marginalise the input of factors such as environment in the development of the organism. In short, Jacob and Monod undertake rhetorical boundary work in order to 'contain' regulation in the genome. This boundary work ultimately rests upon what Doyle sees as a "position of impossible retroactivity," which elides the necessity of a body in which to house the DNA so that it can carry out its work of construction. It is also important to emphasise that Monod and Jacob worked primarily on single-celled organisms, and that assumptions about the general import of molecular biology for genetics and evolutionary theory rested upon what they (although the assertion is more commonly attributed solely to Monod) refer to as "the well-known axiom that anything found to be true of *E. coli* must also be true of Elephants."[25]

Viewed in this light, the notion of gene regulation proposed by Jacob and Monod opens up the possibility of problematising the clear boundaries associated with molecular biology. This is the view expressed by Michel Morange—perhaps surprisingly, given his assessment of Monod's anti-Lysenkoism—in his account of the French contribution to Evolutionary Developmental Biology ("Evo-devo").[26] Evo-devo is a relatively recent attempt to bring together the fields of genetics and embryology, which diverged with the emergence of molecular biology. Morange argues that French biologists' taste for heterodoxy, maintaining for example an interest in the hereditary role played by the cytoplasm, meant that they were able to contribute to the formulation of Evo-devo. What is more, Morange claims that Monod and Jacob's concept of the regulatory gene was French biology's most important contribution to Evo-devo. In this sense, the boundary work carried out by Monod and Jacob in the post-war era continues to reverberate.

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Notes

1. See Denis Buican, *Lyssenko et le lyssenkisme* (Paris: PUF, 1998). See in particular chapter 6, "Lyssenkisme en France," 83-95.
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