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Jacques Monod (1910-1976) and his publications in the “*Annales de l’Institut Pasteur*”

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17 **Abstract**

18 Between 1942 and 1956, Jacques Monod, Nobel Prize winner in Physiology or
19 Medicine, contributed a number of papers to the *Annales de l' Institut Pasteur*, the ancestor
20 of the journal "Research in Microbiology". Circumstances that led him to publish in the
21 "*Annales*" are recalled here.

22

23 *Keywords:* Jacques Monod; Nobel Prize; Annales de l'Institut Pasteur; Diauxic growth;
24 Enzymatic adaptation

25

25 **1. Introduction**

26

27 2010 is the centenary anniversary of the birth of Jacques Monod, who together with
28 François Jacob and André Lwoff received the Nobel Prize in 1965 in recognition of their
29 outstanding contribution to molecular biology. There exists abundant literature concerning the
30 various stages of his life and his scientific achievements (1, 5, 6, 8-10), but the early stages of
31 his scientific career are generally not emphasized. It so happens that, between 1942 and 1956,
32 Jacques Monod published 16 articles in the “*Annales de l’Institut Pasteur*” (3). His first
33 publications in the “*Annales*” were not symbolic of his work, but they represent a decisive
34 turning point in his intellectual pursuit which was to lead to the most prestigious recognition
35 in the international scientific world.

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37 2. From the Sorbonne to the Institut Pasteur

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39 Monod, who obtained a science degree (*licence*) in Paris in 1931, was granted a
40 scholarship so as to learn microbiological techniques at Strasbourg University (France), in the
41 laboratory of Edouard Chatton, a specialist in protozoa. The following year he returned to
42 Paris on a Commercy fellowship to join the “*Laboratoire d’évolution des êtres organisés*”
43 (Laboratory of evolution of living organisms), directed by his former professor at the
44 Sorbonne, Maurice Caullery, and continued working with ciliates. Then, in 1934, he became
45 an assistant in the laboratory of Zoology (Faculty of Sciences, Paris) directed by Charles
46 Perez. It was to be his first paid permanent position. But the job did not suit him well-- he
47 worked in a small dilapidated room, with poor facilities and little exchange with his
48 colleagues.

49 To get away from his dreary laboratory he joined Paul-Emile Victor in a scientific
50 expedition to Greenland on the “*Pourquoi pas?*” He then had the opportunity of learning
51 genetics. He obtained a Rockefeller grant, in 1936 to work on eye pigmentation genes of
52 *Drosophila* in the laboratory of Thomas H. Morgan at the California Institute of Technology
53 in Pasadena (Fig. 1). He discovered another way to perform research founded on collaborative
54 work and critical and fruitful discussions. Back in France, he carried on research for a while at
55 the Institute of Physicochemical Biology, where he continued to work on the model
56 developed in USA.

57 Having kept his position of assistant at the Sorbonne, Jacques Monod came back to
58 work in the laboratory of Charles Perez in 1937, where he began his thesis on bacterial
59 growth using *Escherichia coli* as a model system. This choice resulted from the influence of
60 two men. As a student in zoology, it was during a training course in the Laboratory of Marine
61 Biology in Roscoff (France) in 1929 that Jacques Monod met Georges Teissier for the first
62 time. The latter was a specialist in biometrics, and oriented Jacques Monod’s research
63 towards the study of the kinetics of the growth of bacteria. It was also in Roscoff that Monod
64 met André Lwoff. Lwoff, who was head of the Service of Microbial Physiology at the Institut
65 Pasteur, was well known for his work on growth factors. He convinced Monod to give up the
66 ciliate model for bacteria and provided him with a culture of *E. coli*.

67 Thus, when he decided to begin his thesis, Monod had already acquired wide
68 experience working in many laboratories. This propensity to move from one laboratory to
69 another without settling in reflects the state of mind of Monod at the time, for he was also

70 tempted by a career in music, for which he was extremely gifted. Jacques Monod took his
71 time, but finally chose to pursue his career in biological research.

72 During the Second World War, Monod joined the French Resistance. His laboratory
73 harbored a secretarial office for printing up anti-Nazi pamphlets. Although his commitment
74 considerably slowed down his scientific activities, he managed to finalize his thesis
75 dissertation, which he defended in 1941 under the title "*Recherches sur la croissance des*
76 *cultures bactériennes*". In his memoir published in 1942 (7) he reported on an unknown
77 phenomenon which he termed "diauxic growth" to account for the fact that when bacteria are
78 placed in a medium containing both glucose and lactose, growth is continuous until depletion
79 of glucose; then, after a pause, growth resumes with the use of lactose. André Lwoff then
80 pointed out to him that this phenomenon was certainly a particular example "of enzymatic
81 adaptation". This work also led to a publication in the "*Annales de l'Institut Pasteur*" in 1942
82 (6). Since he was being spied upon by the Gestapo due to his active role in the French
83 Resistance, he left the Sorbonne and took refuge at the Institut Pasteur in André Lwoff's
84 laboratory to study enzymatic adaptation. After the liberation, he engaged in the 1st French
85 Army of General de Lattre de Tassigny. He officially joined the Institut Pasteur as Head of a
86 Laboratory in 1945, where he worked until his death in 1976.

87

88 **3. Publication in the "*Annales*"**

89

90 Under what circumstances did Monod choose to publish his work in the "*Annales de*
91 *l'Institut Pasteur*"? The "*Association des Microbiologistes de Langue Française*" (AMLF),
92 which later became the French Society for Microbiology, was created in 1938 (2). Scientific
93 reports presented in the format of research papers (i.e. including methods, tables and figures)
94 were usually published in the "*Annales*". During the War, the AMLF had difficulty in
95 organizing congresses, and the Institut Pasteur held monthly meetings on its premises. André
96 Lwoff, who was an AMLF member, encouraged Monod to present his data. Until then,
97 Jacques Monod's works had always been presented during formal sessions of the French
98 Academy of Sciences. He thus discovered a more casual atmosphere and an audience which
99 greatly appreciated the originality of his discoveries. This is how 10 of his contributions were
100 published in the "*Annales de l'Institut Pasteur*", including a paper with Elie Wollman (Table
101 1). The initial objective of the "*Annales*" was to publish research work performed in the

102 Institut Pasteur laboratories (both on the mainland and overseas) (3). It was thus within this
103 framework that Jacques Monod published 6 other articles (Table 1).

104 While Monod regularly contributed papers to the "*Annales*" between 1942 and 1947,
105 only three papers were published in the journal thereafter (Table 1). The explanation for this
106 is simple. French continued to be the main language of the "*Annales*" and Monod's work,
107 highly specialized in genetics and molecular biology, addressed an international readership.
108 He thus published in Anglo-Saxon journals. Two of those three papers published during the
109 1950s included results from projects funded by foreign institutions (Table 1: papers 14 and
110 16). Since the second one was also sponsored by a French institution, it was important to
111 publish the results in a French journal. In the third article, Monod returned to the source of
112 his works: bacterial growth. In that paper, Monod set out the theoretical and experimental
113 bases of a method of continuous culture (Table 1: paper 15). It is understandable that this
114 particular work was published in the *Annales*, since Monod had been teaching microbiology
115 courses since 1945. The experimental possibilities offered by this new technique were to be
116 widely used thereafter in French and foreign laboratories.

117 After his death, several of his papers that had been published in the "*Annales*" were
118 reproduced in a volume of selected papers edited by André Lwoff and Agnes Ullmann (4,
119 Table 1), bearing witness to the importance of his contributions. He himself cited three of the
120 papers published in the "*Annales*" (Table 1) in his Nobel Lecture (8).

121

122 **4. Conclusion**

123 Jacques Monod's papers published in the "*Annales de l'Institut Pasteur*" came just
124 after his work on bacterial growth and were a continuation of his thesis. Since they were at the
125 origin of the scientific work which led him to the Nobel Prize, they constitute pioneering
126 research and are important in understanding the future orientation of his research, which was
127 determinant for the continuation of his career: in particular, the discovery of the
128 transcriptional regulation system, in which he analyzed control of genetic expression in the
129 *lac* operon, in *Escherichia coli* and the theory of allosteric interactions (8).

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Legend

Fig. 1: Jacques Monod (1910-1976) in Pasadena, California in 1936.

167 Table 1 Work of Jacques Monod published in the "*Annales de l'Institut Pasteur*"
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	Type	Authors	Title	Year, volume, pages
1.	AMLF report 7 May 1942	Monod, J.	Influence de l'amide de l'acide nicotinique, de l'aneurine et de l'acide ascorbique sur la croissance d' <i>Escherichia coli</i>	(1942) 68, 435-438
2.	AMLF report 5 March 1942	Monod, J.	Sur le phénomène de lyse lié à l'inanition carbonée	(1942) 68, 445-451
3.	ALMF report 2 July 1942 ^a	Monod, J.	Diauxie et respiration au cours de la croissance des cultures de <i>B. coli</i>	(1942) 68, 548-450
4.	AMLF report 4 February 1943	Monod, J.	Influence de la concentration des substrats sur la rapidité d'adaptation chez le <i>B. coli</i>	(1943) 69, 179-181
5.	AMLF report 1 July 1943	Monod, J.	Sur la non-additivité d'action de certains enzymes bactériens	(1944) 70, 57-59
6.	AMLF report 1 July 1943	Monod, J.	Remarque sur le problème de la spécificité des enzymes bactériens	(1944) 70, 60-61
7.	AMLF report 1 December 1943 ^{a,b}	Monod, J.	Inhibition de l'adaptation enzymatique chez <i>B. coli</i> en présence de 2-4 dinitrophénol	(1944) 70, 381-384
8.	AMLF report 2 December 1943 ^a	Monod, J.	Sur la nature du phénomène de diauxie	(1945) 71, 37-38
9.	AMLF report 8 November 1945	Morel. M., Monod, J.	Sur l'utilisation du saccharose par <i>Proteus vulgaris</i>	(1946) 72, 647-656
10.	Research paper ^{a,b}	Monod, J., Audureau, A.	Mutation et adaptation enzymatique chez <i>Escherichia coli</i> -mutable	(1946) 72, 868-878
11.	Research paper ^a	Monod, J.	Sur une mutation spontanée affectant le pouvoir de synthèse de la méthoinine chez une bactérie coliforme	(1946) 72, 879-890
12.	Research paper	Lwoff, A., Monod J.	Essai d'analyse du rôle de l'anhydride carbonique dans la croissance microbienne	(1947) 73, 323-347
13.	AMLF report 3 April 1947	Monod, J., Wollman, E. ^a	L'inhibition de la croissance et de l'adaptation enzymatique chez les bactéries infectées par le bacteriophage	(1947) 73, 937-956
14.	Research paper ^{a,c}	Monod, J., Torriani, A.	De l'amyloamylase d' <i>Escherichia coli</i>	(1950) 78, 65-77
15.	Research paper ^a	Monod, J.	La technique de culture continue: théorie et applications	(1950) 79, 390-410
16.	Research paper ^{a,b,d}	Rickenberg, H., Cohen	La galactoside-perméase d' <i>Escherichia coli</i>	(1956) 91, 829-857

		G., Buttin, G., Monod, J.		
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171 AMLF: Association des Microbiologistes de Langue Française

172 ^a Work reproduced in the selected papers (4)

173 ^b Work cited in the Nobel lecture (8)

174 ^c Work funded by the National Institute of Health

175 ^d Work funded by The Rockefeller Foundation, Jane Coffin Child's Memorial Fund
176 and the "*Commissariat à l'Energie Atomique*"

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