only to tell him that she plans to marry another man. Jacob skillfully uses this truly "monotonous and uneventful" period of his life to recount various past events. Finally discharged from the hospital and the Army, still partially crippled and with metal splinters in his body, he is lonely, unable to make up his mind about the future. He tries journalism, filmmaking, work in a penicillin production facility. He decides to complete his medical studies, to which he is admitted despite his lack of the necessary formal qualifications, thanks to his military record.

By the time he receives his medical degree in 1947, Jacob realizes that practicing medicine is not for him either. He meets a young geneticist with wartime experiences similar to his, who is studying mutations in yeast in the laboratory of Boris Ephrussi. Jacob is amazed to learn that such vanguard scientific work can be done by people who do not seem to be any cleverer than he. So why not become a research biologist? After several unsuccessful attempts to be accepted by laboratory *patrons*, including André Lwoff at the Institut Pasteur, he is finally taken on by Lwoff. The year is 1949. Jacob has never been able to figure out why Lwoff caved in—maybe he happened to be in a good mood that day because he had just discovered prophage induction. "Had I been he, I would surely not have accepted into my laboratory a chap like myself."

Jacob has been saved. The remodeling of his inner statue from the dispirited, floundering war veteran into the world-famous molecular biologist begins. It proceeds slowly at first, with Jacob wondering how he will ever penetrate that mysterious universe of science, its folklore, its language. (When I met Jacob in the following year, I still thought I knew more than he did and patronized him with advice about his research projects.)

The final third of *The Statue Within* does bear some resemblance to scientific autobiography, describing the ambience of what we called "Lwoff's attic" at the Institut Pasteur, its permanent and transient occupants and the problems that exercised them during the perinatal stage of molecular biology. These descriptions are mainly brief sketches lacking a didactic purpose. They are not meant to provide a deep understanding of Jacob's classic experiments that led to our present understanding of the regulation of gene expression. (The predicate "classic" is mine. An untutored reader could infer from Jacob's modest narrative merely that he and other folks in the attic found some of his results and theories exciting, but not their extraordinary significance for biology.) He does not show the inner statues of the other scientists through encounters and associations with whom he is resculpting his statue. Except for Lwoff (whom Jacob could never bring himself to address in any way other than "Monsieur") and Monod, who now take over the dominant roles previously played by parents and relatives in the remodeling of the statue, Jacob's colleagues are merely limned with a few incisive phrases. For instance, a seminar presented in the attic by the "short, stocky . . . featherweight boxer" Sol Spiegelman is described in terms of a *corrida*, with Spiegelman as *toro*, the "imperturbable" Lwoff as *presidente*, the "elegant" Monod as *matador*, and with Roger Stanier (the Canadian "debonair giant"), Melvin Cohn (the "uninhibited young American"), and Martin Pollock (the Englishman with the "handsome, insolently aristocratic" face) as *banderilleros*, while the crowd of *aficionados* of enzyme induction shouts "*olé*!" at each pass.

By 1954, Jacob has been granted a D.Sc. by the Sorbonne, on the basis of a thesis presenting his fundamental discoveries about the genetic nature of proviruses. But he still feels that he has jumped on a moving train without a ticket. He sees only one way to avoid getting caught by the conductor: "Charge, head lowered. Attack on all fronts." So he begins his collaboration with Elie Wollman. Within three years, they have discovered that the bacterial genome is circular and that it is transferred in a linear order from donor to recipient cell in bacterial conjugation. With Wollman gone to Berkeley (for a stay in my laboratory), Jacob joins forces with Monod to apply his recently acquired insights into the mechanism of bacterial conjugation to the problem of enzyme induction with which Monod has struggled for the past decade. With the visiting American Arthur Pardee ("baby face, timid eyes behind glasses hiding the remarkable experimenter") they carry out the PAJAMA (Pardee-Jacob-Monod) experiment, which leads to the concept of the repressor as the regulator of gene expression. Jacob realizes while sitting in a movie theater some months later that the site of regulatory action of the repressor must be a particular stretch of DNA, the "interruptor," later to be designated "operator." Thus the operon theory of the regulation of gene expression is born. Monod is not enthusiastic about this idea at first but, eventually warming to it, proposes some critical tests. That day in 1958, Jacob says, "marked a turning point in my scientific life": at last he has a ticket to show the train's conductor. He and Monod design and carry out experiments that validate the repressor-operator interaction concept.

Jacob travels to Pasadena with Sydney Brenner ("squarish head, his eyes blue beneath blond brows, enormous, hirsute, shaggy . . . a Frans Hals [portrait] . . . behind his slightly sarcastic, even satanic visage, his smile revealed a child's face") to collaborate with him to try to validate experimentally the notion of a metabolically unstable messenger RNA guiding protein synthesis. The idea of the messenger RNA emerged some months earlier as a necessary adjunct of the operon theory, in discussions with Brenner and Crick in Cambridge. Matthew Meselson's laboratory at Caltech seemed to be the best place to demonstrate its existence. After several weeks of unsuccessful experiments, Brenner suddenly discovers the source of their troubles. In a final, simple experiment, done in extremis just before leaving California, they achieve their goal: messenger RNA does exist. Back in Paris, Jacob and Monod put the final touches on their historic paper "Genetic regulatory mechanisms in the synthesis of proteins" and mail it off to the *Journal of Molecular Biology* on Christmas Eve 1960.

As Jacob is walking home in the snow through the Luxembourg Gardens, he recalls the inner statue of little François. He is thinking of his childhood Christmas holidays in Dijon, of the park where he used to play alone, frightening himself by populating it with robbers, savages, and wild beasts. As he is leaving the Luxembourg Gardens, he suddenly thinks of an experiment he could do on the mechanisms of cell division. A very simple experiment in fact. It would suffice to. . . .

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Levels of Representation

Consciousness and the Computational Mind. RAY JACKENDOFF. MIT Press, Cambridge, MA, 1987. xvi, 356 pp., illus. $27.50. Explorations in Cognitive Science, vol. 3. A Bradford Book.

In the early years of this century, a group of German psychologists at Würzburg claimed that thinking is not always accompanied by imagery, whereas another group of psychologists led by Edward Titchener at Cornell argued to the contrary. This clash between two opposing introspective philosophies—Kantian and Humean, respectively—became known as the "imageless thought" controversy. It was interminable and irresolvable, and its principal result was behaviorism. The study of consciousness

was declared out of bounds, and for 40 years psychologists tried to do psychology without looking into the mind. This regimen was neither revealing nor rewarding, and, since World War II, scientists in a number of disciplines have returned to the study of mental phenomena. Consciousness was the first faculty to be dropped by the behaviorists; it has been the last to re-enter the fold of modern cognitive science. A sign of the current interest in its workings, however, is the publication of Ray Jackendoff's book, the first on the topic to be written by a linguist.

Like most cognitive scientists, Jackendoff assumes that the brain carries out computational processes that are organized in a highly modular way. These processes are unconscious. Indeed, Jackendoff drives a wedge between consciousness and computation. "I find it every bit as incoherent," he writes, "to speak of conscious experience as a flow of information as to speak of it as a collection of neural firings. It is completely unclear to me how computations, no matter how complex or abstract, can add up to experience." His grounds for this view are that we perceive not computations but objects in the world, and these objects have shapes and properties. An object can be square and blue and taste slightly of salt, but there are no square, blue, or salty computations.

In short, there is a mystery about how the quiddities of the conscious mind derive from computations, and Jackendoff takes this mystery—for which he has no solution—to be as deep as the traditional mind-body problem. He draws from it two important morals. First, the contents of consciousness can have no causal effect on the computations of the mind. Consciousness is an epiphenomenon that, in T. H. Huxley's phrase, is merely the bell on the clock, not the mainspring of action. Second, anything that we can be aware of depends in some yet to be fathomed way on the computations of our minds. This assumption licenses the meat of the book sandwiched between its layers of philosophical analysis: an expert study of the mental structures underlying vision, language, and music.

The burden of this study is that each faculty has its own chain of levels of representation, though the chains may intersect. Thus, as the late David Marr argued, the array of retinal intensities is used to compute a representation of the major regions of intensity in the visual field, which in turn is used to compute a representation of the relative depths from the observer of each point in the scene (the so-called "2½ D sketch"); and this representation is used to compute a full three-dimensional model of the objective spatial relations among objects. Jackendoff argues for analogous levels of representation for language (sounds, phonology, syntax, and meaning) and for music (sounds, and a further five levels from the musical surface to a rich representation of abstract structure). Few cognitive scientists would quarrel with Jackendoff's case for levels of representation, but the particular levels he proposes are controversial. Part of the difficulty is that, in principle, an intermediate representation can be cut from the chain and the two loose ends tied together to form a single process. Hence, the question of which levels exist calls for an experimental answer, and there is as yet no decisive evidence either for Marr's 2½ D sketch or for some of the levels postulated by Jackendoff.

Of course, you are not aware of all the levels. And the centerpiece of the theory is, in fact, that you are only ever aware of the phonological level, the 2½ D sketch, and the musical surface. Consciousness, in other words, always contains imagery. But if you are aware only of these intermediate levels, you can never be aware of the significance of anything. You can be aware of the words that I utter and my tone of voice, but you cannot be aware of what they mean. (By an additional binary mechanism, Jackendoff allows that you can be aware that the utterance is meaningful.) The theory seems to be based on confounding two distinct states: being aware of what an utterance means, and being aware of the form in which its meaning is mentally represented. The latter is impossible, as Jackendoff points out; but it does not follow that the former is impossible. People can indeed be aware of the meaning of an utterance, and bilinguals can even grasp it without being aware of the language in which the utterance was spoken. Alas, we have come full circle back to the imageless thought controversy, and there still seems to be no way in which to resolve it.

Consciousness and the Computational Mind is provocative, highly informed, and essential reading for anyone interested in a scientific understanding of the mind. It ranges widely over language, music, and vision and calls for an equal sophistication on the part of the reader. But must we accept its thesis that consciousness is merely an appendix, a useless mental organ that becomes inflamed to no purpose? Jackendoff himself is not happy with this position, but he sees no retreat from it. An alternative hypothesis, however, posits that there are processes that construct the contents of consciousness and that these contents determine the course of still other computations. Their results can modify our behavior and our subsequent conscious experience. In this theory, unlike Jackendoff's, the contents of consciousness are not freewheeling epicycles but a central link in the causal chain that governs our behavior.

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Vertebrate Phylogeny

The Biology and Evolution of Lungfishes. WILLIAM E. BEMIS, WARREN W. BURGGREN, and NORMAN E. KEMP, Eds. Liss, New York, 1987. viii, 383 pp., illus. $49.50. Also published as *Journal of Morphology*, supplement 1 (1986). Based on a symposium, Denver, CO, Dec. 1984.

Despite the fundamental importance of lungfishes (Dipnoi) as a clade standing at a pivotal point in vertebrate evolution, there has been no attempt prior to this book to organize and synthesize information on most major aspects of their biology and evolution. Furthermore, most of the papers in the volume present significant new information and are not mere reviews of previously published data.

Lungfishes have, since the discovery of the first living species in 1836, occupied a key place in discussions of vertebrate phylogeny. They represent a clade of ambiguous morphology, allied with both amphibians and fishes by investigators in the last century. Lungfishes possess a confusing mosaic of traits. Some characteristics, like the morphology of the circulatory system, indicate a close phylogenetic relationship with tetrapods. Other aspects of form are shared with ray-finned fishes and coelacanths. At the same time, lungfishes possess numerous specializations, notably in skull and jaw morphology, that confound attempts to determine homologies across lower vertebrate clades.

The debate on the phylogenetic position of lungfishes is not resolved in this volume, but the prominent role accorded to historical and systematic analysis (usually lacking in books of this type) is welcome. Several of the papers included are in sharp and open disagreement on the major patterns of lower vertebrate evolution. Schultze, Campbell, and Barwick advocate the view that coelacanths are the closest living relatives of tetrapods, with lungfishes being the closest living relatives to both of these clades together. On the other hand, Forey emphasizes characters indicating that lungfishes are the relatives of terrestrial vertebrates, with coelacanths as the outgroup taxon. Many other disagreements on details of lower ver-