Claude Debru*

Scientific progress: A qualitative view

THE AMERICAN PHILOSOPHER Nicholas Rescher published in 1978 a book entitled *Scientific Progress.A philosophical essay on the economics of research in natural science*, which is quite interesting because it has both a quantitative and a qualitative vision of scientific progress, and because it includes the perception by the scientist of the present state of completeness or incompleteness of its discipline and thus of its future. I would like to borrow from this book a fundamental idea, regarding the ratio between the amount of what is considered or perceived as unknown at a certain time, and the amount of what is considered or perceived as being known. Rescher thinks that the ratio between the known perceived as such and the unknown perceived as such oscillates throughout history. Let us first concentrate on these ideas of Rescher. Then we will try to analyse examples borrowed from twentieth century natural science in order to illustrate the relevance of these ideas and perhaps to go further and deeper.

Rescher's book was published at a time when many questions about the future of economic growth (including zero growth), and about the possibility of ensuring continuing and increasing funding for science were asked. The book conveys an optimistic view of the continuation of scientific research against the view that at one day or another scientific research would have completed its task and thus would cease. Rescher goes back to different philosophical views on scientific progress which were expressed during history and distinguishes between five different conceptions regarding the future of science:

(1) the view that science will end because nature is finite;
(2) he view that science will indefinitely approach, in an asymptotic way, a full knowledge of nature without reaching this full knowlege of a finite nature;
(3) the view that science will end because our understanding is itself finite and will reach its limits;
(4) the view that science will continue because human understanding will never reach its limits;
(5) the view that science will continue indefinitely because there is no limit whatsoever to its extension.

All these five views have been held throughout history. What is most striking however is that when scientists, or philosophers, say that science is reaching its limits (like in physics at the end of the nineteenth century), then in fact new techniques and new experiments create revolutionary developments. These judgments regarding the future are obviously matters of belief. This is precisely because views regarding the future of science are matters of belief or perception that Rescher introduces these ideas of perceived knowledge, or the extent of perceived knowledge versus perceived ignorance. Rescher writes the ratio r = the extent of perceived knowlege/the extent of perceived ignorance, in order to give a kind of mixed quantitative and qualitative view of the future of science, of its extension or limitation as they are perceived at a given moment. He tries to picture how this ratio evolves throughout history since 1700. On the ground of several sources, he claims that this ratio oscillates strongly. It means that during some periods of time science is considered as almost complete, and that during other periods science is considered as starting afresh, almost anew, and between these periods, there are other periods when people realise how incomplete science is, and periods when science is considered as more and more approaching completeness.

This picture of science deserves much attention because it introduces the idea of cycles in a theme, scientific progress, which was very often viewed as a pure linear matter. It is certainly not a matter of

* Department of Philosophy, Ecole normale supérieure, Paris, France; email: Claude.debru@ens.fr.

chance if this mixed quantitative and qualitative, and cyclical view of science was designed by somebody having a strong background in economics. I wish to keep in mind this cyclic view of science when discussing more specific examples borrowed from the history of natural science in the second half of the twentieth century. The example I will choose is taken from developments in the field of neuroscience which underwent tremendous developments in the last fifty years with the view that progress in the field could continue in the sense that people did not see any limitation for neuroscience. So you have a case of continuing increase in knowledge, a more and more detailed and precise view of the workings of the brain. But if you look at more specific parts of brain science, you may get a more cyclic sense of scientific progress — cyclic precisely in the sense advocated by Nicholas Rescher, in the sense of the changing perception, by the community of scientists, of the future of their field. This is precisely the topics which I want to deal with now: great hopes, discouragement, and hopes again.

The specific domain I will choose is sleep and dreaming physiology. Sleep physiology and psychophysiology underwent drammatic changes when Nathaniel Kleitman and Eugene Aserinsky working in Chicago discovered, in 1953, a special phase of sleep (which they called rapid eye movement sleep), which turned out to be associated with deaming, and which they considered as light sleep. Then, in 1958 in Lyon (France), Michel Jouvet added a crucial observation, that a special phase of sleep with low voltage fast activity in the cortex was accompanied by muscular atonia and that the animal was in deep sleep (very difficult to awake). He called that « paradoxical sleep », because he was struck by the coexistence of an intense internal activity of the brain and a lack of any or almost any peripheral expression. He interpreted that phenomenon as a third state of « vigilance » together with wakefulness and slow-wave sleep. This series of different discoveries opended up tremendous research developments which were rapidly accelerating in the nineteen sixties, then decelerating in the nineteen eighties when the field entered a more difficult phase, then accelerating again more recently.. This cyclic structure is very striking indeed in the particular domain. It fits perfectly a feature which is mentioned by Rescher in his book and is taken from an Eastern scholar, G.M. Dobrov, who pictures scientific progress by a series of sigmoid curves attached to each other. This kind of picture may apply quite easily to several parts of sleep physiology, including biochemical mechanisms, and psychophysiology.

Let us start with psychophysiology. The discovery of rem sleep by Aserinsky and Kleitman was the starting point of many developments, performed mainly later by Prof. William Dement (now at Stanford), who was able to combine electroencephalography and dream reports. Researchers awakened the subjects during rem sleep and asked them to report about their dreaming experience. Researchers thought that in this way they had at hand a correlation between psychoanalytic processes and physiology, which provided the material basis of expression for these unconscious processes. So there were big hopes in the nineteen sixties to combine psychophysiology and psychoanalysis. Another question became more pressing: is dreaming occurring only during rem sleep? This question could also be relevant to the previous question: what are the physiological processes related to Freudian mechanisms? How do physiological and psychological mechanisms mirror each other? These questions (among many other ones) were formulated in this way at that time in the mid-sixties. I do not think they could be formulated in the same way again now, and we will see that the process of formulating and reformulating questions is particularly important in natural and experimental science. So let us look at each of these questions.

Is dreaming occurring only during rem sleep? Some researchers, including the American psychiatrist David Foulkes, thought that there should be a continuing mental activity during both phases of sleep, slow wave sleep and paradoxical or rem sleep. Foulkes thought that this continuing mental activity should have a different form according to the two different phases – a more vivid, more imaginative form during the rem phase, and a more « thought-like» form during slow wave sleep. This was pure psychophysical parallelism. But this was never really confirmed. As a matter of fact, people discovered that some sort of dreaming could occur during slow wave sleep as well as during rem or paradoxical sleep. They had statistics, they tried to devise criteria, classifications of mental activity etc. But nothing really clear went out in this field, and when David Foulkes reviewed the whole field in 1996, the general tone of his speech was discouragement. Presently, thanks to modern brain imaging techniques and to more sophisticated tools in cognitive psychology, the field starts again. Indeed, researchers working with brain imaging techniques were recently able to show that some unexpected activation of visual and auditory cortical areas does occur during slow wave sleep, and may provide a physiological basis for dreaming activity in slow wave sleep. However, the behavioral

aspect of rem sleep (the fact that specific patterns of behaviors which are normally inhibited in rem sleep may be liberated in conditions of disease in man or surgery in animal) does not occur at all during slow wave sleep — so that the old division keeps its solidity in a way. Behind this, are questions of biological function which I do not want to deal with here.

If we turn briefly to the purely physiological, biochemical aspect, we can observe that there were big hopes in the sixties, great disappointments in the seventies, that researchers thought the field was no more of interest and should be abandoned in the early eighties, and that that the field started again in the nineties, thanks to the development of genetical studies on narcoleptic dogs mainly. Essentially, the field evolved from a rather simple experimental paradigm involving a few neurotransmittors (very few were known at that time) and based on neuroanatomical, pharmacological and experimental evidence, to a much more complex and realistic picture involving many neurotransmitters, neuronal circuits etc. Inbetween, there were critical developments which I witnessed when I was as a philosopher a member of Michel Jouvet's laboratory in Lyon. To summarize these developments: seemingly very solid pieces of evidence in functional anatomy of the brain, including lesions and electrical stimulation of specific nuclei whose activity could be related to behavioral phenomena in the cat, other pieces of evidence obtained thanks to new histological techniques in the mid-sixties, and pharmacological evidence obtained by using drugs which would interefere with monoamine metabolism, allowed to propose the so-called « monoamine theory of sleep », according to which the serotonin molecule would play the triggering role in the appearance of the paradoxical (or rem) sleep phase. In the late seventies, doubts regarding this theoretical scheme began to accumulate, largely due to more specific electrophysiological evidence, and also due to chronic pharmacological experiments. A crucial experiment devised by Michel Jouvet in the early eighties, using transfers of cephalospinal fluid between instrumentally sleep deprived and pharmacologically sleep deprived animals allowed him to conclude unequivocally that the serotonin molecule was only a sufficient, and not a necessry condition for paradoxical sleep to occur. The search for other molecules and other brain localisations for sleep mechanisms began, in which new data taken from genetical and biochemical studies played an important role, so that the field was starting again in a very active way. It should be mentioned also that the study of more theoretical, functional aspects of sleep physiology never stopped, thanks mainly to lesion experiments on cat, which could display specific behavioral patterns during the paradoxical phase. This remains also a major aspect of Michel Jouvet's contribution to sleep physiology.

To conclude: let us give some comments on reformulating questions. Nicholas Rescher's comments on Thomas Kuhn's scientific revolutions dealt with the idea of incommensurable paradigms which in his view makes the concept of scientific progress impossible to understand. I agree with Nicholas Rescher on the point that the idea of scientific revolution (or Gaston Bachelard's « rupture épistémologique ») is somehow exaggerated. Things are much more continuous most of the time. The process of formulating and reformulating questions is essential in natural science. For instance, the question which was asked in the nineteen sixties, whether the serotonin molecule is a necessary and sufficient condition of the occurrence of paradoxical sleep or not, couldn't be asked any more today. Researchers would rather ask typically another kind of question: which kind of interaction does occur between this particular neurone and this other particular neurone using this particular neurotransmitter. The final suggestion would be that we should try to combine the strong subjective oscillation regarding the perception of scientific progress and the objective, sigmoidal picture of progress.

Selected bibliography

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