Chapter 1

Introduction

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The authors in this anthology agree with each other on some very basic issues. First, in the developed world 'Reductionism Rules'. Scientists who use reductionist methods predominate in raw numbers, publish the most papers, are cited the most frequently, get the most grant money, etc., while more holistic scientists are increasingly shut out. For example, the University of Leiden recently closed five of the nine research groups in its Institute for Evolutionary and Ecological Sciences. Whether or not one thinks of these closures as an instance of the unfortunate effects of reductionism on science, depends on one's view of evolutionary theory. Is evolutionary theory a bulwark against reductionism, or is it itself reductionist to its core? Contributors in this anthology represent both sides of this dispute.

A second point on which the authors in this anthology agree is that reductionism, as successful as it has been on a host of counts, is seriously inadequate. It must be *supplemented* with more holistic science. To understand nature in all its vicissitudes, methods from the most reductionist to the least reductionist must be used. Hence, anti-reductionists are forced, like it or not, to advocate pluralism. For example, Robert Williams concludes that 'We must not despise reductionism. However, it has to be put in a proper perspective'. Too often reductionism and anti-reductionism are presented as if they are in diametric opposition when all that separates them is degree of emphasis. As Alfred Tauber observes, 'reductionism' and 'holism' cannot be defined in isolation from each other. An unsteady balance exists between the two. 'Holism and reductionism are inexorably coupled and cannot be defined independent of each other'. As a result, like so many other contributors to this volume, he embraces a 'pluralistic approach'.

Promises and Limits of Reductionism in the Biomedical Sciences
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Some of the more enthusiastic reductionists disagree. As they see it, reductionism is the only game in town. Their message to their fellow scientists is either get on the bandwagon or be left behind. Calls for pluralism simply show how feeble the alternatives to reduction have become. Anti-reductionists would not be calling for pluralism if they had any chance of winning. Pluralism is the last resort of losers, at least so claim the more enthusiastic reductionists. Dorothy Nelkin quotes a whole series of such exuberant pronouncements by reductionists: behavior is to be reduced to cell biology, beliefs are chemical events in the brain, and genes can be found for everything from alcoholism to heterosexuality. How literally we are to take the claims made by reductionists is not always easy to tell.

Philosophers and scientists: pooled resources

In the past, philosophers have expressed their views on reductionism, whether pro or con, in terms of the traditional philosophy of science, the sort of philosophy of science that arose in the works of Sir John Herschel and continued to at least Carl Hempel. Philosophers working in this tradition acknowledge numerous differences of opinion on philosophical issues, but they tend to address the same sorts of problems and produce variations on the same variety of themes. As Claude Debru remarks, the terms which were used in the 'nineteenth century discussions remain the ones which we use now'. For example, philosophers in this tradition tend to view science in terms of the 'wedding-cake model' and interpret reductionism as a relation between laws and theories (see Alex Rosenberg and Kenneth Schaffner). However, philosophers within this tradition can be found arrayed on both sides of the dispute over reductionism. They accept the general outlook of the traditional philosophy of science, but some conclude that reductionism is a viable position while others conclude that it is not. In this anthology, those authors who rely most heavily on traditional ways of carrying out the philosophy of science nevertheless reject reductionism. Hence, accepting the methods of traditional philosophy of science does not automatically make one a reductionist, or worse yet, a 'positivist'.

Philosophers are not the only ones who have involved themselves in the dispute over reductionism. From the first, scientists have also joined in the fracas. In fact, throughout its history, both scientists and philosophers have made major contributions to the philosophy of science. The two groups have pooled their conceptual resources. This arrangement has not always run smoothly. Scientists can be found huffing that 'philosophers of science would not talk such nonsense if only they got their hands dirty and learned a little science', while philosophers can be found reminding scientists that the dispute over reductionism is a philosophical dispute. Debru, in his brief history of the transition from nineteenth century ideas on reduction in physiology to non-reductive explanations in twentieth century biochemistry, complains about how molecular biology has been parodied. After all it is molecular biologists who have shown that biological molecules are ‘not only very complicated molecular machines’, but also the ‘results of the whole history of life’. So the ‘quarrel of reductionism which is raised by some philosophers against molecular biologists is entirely unfair’. Stanley Shostak warns of philosophers ‘bearing gifts’. Rosenberg concedes that biologists are ‘unlikely to be interested in philosophical disputes about the nature of explanation’, but regrettably ‘they have to be, if they wish to decide intelligently about whether to embrace reductionist or non-reductionist methodology’.

The contributors to this anthology present an appropriate balance between science and philosophy. Several papers include extensive discussions of particular areas in science, showing the difficulties of possible reductions. For example, Marc Van Regenmortel examines the immune system in great detail to show how far reductionist modes of explanations can be extended and why they are not sufficient. Constructing one-dimensional profiles that allow the prediction of successful antigenicity rarely exceeds a 60 % success rate, while the approximate location of binding sites in the folding protein is achieved in only about 50 % of the cases. Schaffner explains how overly simple views of molecular biology led early philosophers to reject reductionism – the relation between Mendelian genetics and molecular biology are many – many. However, as molecular biology developed, the apparent simplicity of molecular mechanisms gave way to mind-boggling complexity. Schaffner describes attempts to deal with this complexity that rely on genetic chip technology. However, ‘genes and mRNA levels are too indirect a measure of the phenotype, which is where the action is’, and concludes that the initial focus on DNA and genetics has been misleading. Biological activities and interactions take place not at the level of genes but at the level of proteins, including post-translationally modified proteins. The rise of ‘proteomics’, which is the study of the expression and function of proteins in different biological contexts, is a clear indication that scientists have realized that they need to move beyond genetic reductionism.

One important point of disagreement among reductionists and anti-reductionists concerns ‘emergent’ properties. The latter are properties possessed by a complex whole but not by its parts. Van Regenmortel lists a whole series of emergent properties. First on his list is the viscosity of water. Water is viscous, while individual molecules of water have no such property. The issue is which emergent properties can be explained in terms of their constituent parts, including their relations, and which cannot. Water is about as simple a molecule as one is likely to find. If it withstands reductive analysis, then one need not worry about proteins and molecules of DNA. The record here is mixed. Williams argues that on the basis of quantum theory, we can provide a complete explanation of the structure of water in its gaseous phase, but not in either of its condensed phases. Thus, none of the properties of water vapor are emergent, regardless of what people thought in the past, but some, if not all, of the properties of liquid water and ice may turn out to be unreducibly emergent. The message is that deciding which properties are emergent and which are not is far from easy. Debru tells a comparable story for hemoglobin. However, it is clear that a melody arising from notes, the salty taste of sodium chloride and the antigenicity of a protein are emergent properties.

Function, selection and laws of nature

One difference between reductionists and anti-reductionists is that reductionists tend to express their position in terms of processes and laws, while anti-reductionists prefer to talk of mechanisms and systems. On the 'wedding-cake model', phenomena at various levels are related by inference – laws at higher levels are deduced from laws at lower levels. Complex systems to the contrary are made up of parts. Deriving a higher-level generalization from a lower-level generalization is not the same thing as dividing a whole into its parts. Evolutionary theory deals with various processes, e.g. the influence that population size has on the rapidity of evolutionary change. However, it also deals with structure, e.g. population structure. For anti-reductionists finding out how the machinery works is explanatory in and of itself, even in the absence of a knowledge of the process laws governing this machinery.

As Van Regenmortel observes, in contrast to 'reductionists who emphasize causal explanations, anti-reductionists favour functional and selectionist explanations for biological phenomena'. Anti-reductionists emphasize structures and their emergent properties. Among these structures are functional systems. The latter are not only systems, but the peculiar way in which they are individuated provides an additional barrier to reduction. Functional systems are currently defined in two ways – as Wright functions and as Cummins functions. Wright functions (Wright, 1976) are delineated in terms of descent via selection processes. They are naturally selected effects. As both Van Regenmortel and Rosenberg remark, natural selection for adaptations is 'blind' to differences in physical structure that have the same or roughly similar effects. Hence, no regularities relating structures can be found in functionally defined systems. Any laws must relate functions, not structures.

One additional complicating factor is that organisms seem to exhibit many fewer functions than structures. This asymmetry may be due to the emphasis that biologists have placed on structures in the past, or it may reflect a fundamental difference in the living versus the non-living world. In any case, the presence of functional explanations in biology and the analysis of 'function' in terms of selection 'makes biology an essentially historical discipline' (Rosenberg). Just in case anyone might think that functional explanations are reserved only for higher levels of analysis, Rosenberg presents a functional explanation entirely in the context of molecular biology.

Reductionists couch their explanations in terms of processes. One problem with reductionism is that the old positivist notion of laws of nature has fallen on hard times. It has never seemed all that appropriate for biology anyway. In fact, numerous biologists and philosophers of biology have argued that biology has no laws. If laws are as central to our understanding of the external world as positivists have supposed, this is a damning conclusion. As a result, several biologists and philosophers of biology have argued that once the notion of a law of nature is freed from certain simplistic assumptions, biological laws do exist, e.g. the basic principles of selection (see Sober, 1993 and Rosenberg in this volume). Others agree that there are no biological laws but that is all right because there are no laws in physics either! Even the most fundamental laws in physics require all sorts of provisos, including *ceteris paribus* clauses. Even these laws apply only to the most fundamental and general characteristics of natural phenomena. We take laws governing planets as seriously as we do because they are special instances of more fundamental processes, i.e. the relation between masses as such. Of course, as general as these laws may be, we humans can solve them for only three, possibly four bodies at a time.

Van Regenmortel objects to linear reductionistic causal laws in which one factor is singled out and given undue weight as *the* cause when all the various factors play a role, frequently a necessary role. Van Regenmortel, Steven Rose and Kenneth Schaffner take issue with the claim that genes are self-replicating molecules. Van Regenmortel objects that genes 'provide information only in the context of other genes and they are expressed only in the context of a particular cellular, extracellular and extraorganismic environment. Genes certainly do not act alone and they are not even self-replicating'. Rose agrees. 'One of the central features of DNA as a molecule is that it cannot simply and unaided make copies of itself; it cannot therefore ''replicate'' in the sense that this term is usually understood . . . What brings DNA to life, so to speak, is the cell in which it is embedded' (see James Griesemer and Schaffner for similar objections).

Of course, no one would object to any of the preceding claims about DNA. They can be found in any introductory textbook. However, there are two issues with respect to self-replication: the warrant for selecting one part of the complex story and terming it *the* cause and the connotations of the term 'self-replication'. Although numerous factors play a role in any causal situation, frequently we select one as the cause and demote all others to supplementary conditions. For example, one afternoon I come home from work and find my house burnt to the ground. I might ask, 'What caused my house to burn down?'. To be told that oxygen did it would be clearly wrong-headed. Of course, oxygen is a necessary part of the entire story. So is the fact that my house is built of flammable material, has no sprinkler system, and on and on. However, if a space heater set some curtains on fire, I want to know about that. It was the cause of the fire. An insurance broker may nevertheless want to argue that I caused the fire by keeping the heater on and placing it too close to the curtains.

Perhaps the message of the 'self-replication' objection is that scientists must always give complete explanations all the time. Quick, shorthand references are never good enough. Another message is that 'self-replication' carries inappropriate connotations. For example, one of the most common examples of self-replication is photocopying machines (see Griesemer). A page is copied, this copy is copied, and so on. However, it seems strange to refer to this process as 'self-replication' because all of the work is being done by the machine. The paper copies are almost incidental parts of the process. The message for the self-replication of genes is that reference to the relevant developmental machinery is being omitted (see Schaffner). One response to the above arguments is that in both cases all of the machinery was devised to fulfill one purpose – passing on information via copies – and it is this information that is crucial to selection processes.

Even if one is willing to accept as laws of nature the sort of hedged bets that we find in both physics and biology, a difference remains between the two. With respect to quite a few of the most general laws in physics, only a very few additional assumptions need to be made. We know what they are and how to take them into account. Comparable laws in biology are noteworthy by their absence. Too many factors matter, and they vary too rapidly and in too many different ways. Reductionist explanations in terms of a single causal factor are thus singularly deficient in biology.

History, selection and laws of nature

One commonly hears that biology is fundamentally historical in a sense missing in physical phenomena. Of course, both biological and purely physical processes have histories. Just as paleontologists reconstruct phylogeny, cosmologists reconstruct the history of planets, star systems, and even the entire universe. All of these activities are equally historical in the sense that historical reconstruction is central to the activity (see Rosenberg).

A second source for the conviction that biology is historical in a sense different from physics is a deep and pervasive misunderstanding about biological taxa such as Vertebrata and *Homo sapiens*. Until quite recently, everyone has treated biological taxa as beings kinds of some sort. Just as gold consists of all the atoms with the atomic number 79, trumpeter swans have certain sorts of feathers, eggs, and mating calls. Although it has taken a while, biologists have finally recognized the implications of evolutionary theory for biological taxa. The latter as monophyletic groups diagnosed by homologous characters are not classes like electrons or substances like gold, but historical entities. They are historical entities in that they have a beginning in time, survive for a while and then become extinct, never to recur. However, in this respect they are no different from purely physical historical entities like the Earth or Alpha Centauri. Biological taxa seem to pose problems for biology only if one puts them in the wrong metaphysical category.

However, biology does differ from physics in one very fundamental way, i.e. the crucial role that selection processes play in biology. In response to our changing understanding of biological taxa, those who want to argue that laws can be found in biological phenomena move up a level from biological taxa to kinds of taxa, e.g. peripheral isolates. According to one prevalent view in evolutionary biology, small populations isolated at the peripheries of species are the best candidates for the production of new species. All natural phenomena take place in time and in this weak sense have ‘histories’, but most natural phenomena need not be characterized in terms of these histories. However, in cases of selection processes, histories are crucial. In order for selection to perform the functions that it does in biological evolution, the relevant entities must be related by descent (see David Hull and Rosenberg).

A common device used to explain statistical frequencies is an urn filled with balls of various colors. You take out a ball and see what color it is. You toss the ball back into the urn again, stir the balls and take another ball. As you proceed, you can become increasingly confident that you are discovering the relative frequencies of the balls in the urn. This is not how selection works. Starting at the genetic level, numerous genes of various sorts are produced. These genes proliferate. Only a small percentage of these genes succeed in producing copies of themselves which proliferate in the next generation, and so on. No balls get thrown back in the urn. The genes that do succeed in surviving and reproducing are connected through time. All phenomena have histories. These histories can be studied, but what makes selection processes 'historical' in a special sense is that they incorporate in their make-up an historical element – replication. Parallel observations hold for the immune system as well. It too embodies a selection process (Van Regenmortel; for a differing view, see Griesemer).

Many aspects of life on Earth are contingent, e.g. that all proteins used by organisms are *levo* rather than *dextro*. However, if biology is to count as science in the sense left over from the early days of philosophy of science (e.g. from Herschel to Hempel), some very fundamental phenomena that are uniquely biological must be characterizable in terms of laws. Of course, these laws need not be 'lawful' in a sense more rigid than comparable laws in physics. *Ceteris paribus* clauses will be necessary. If Newton's laws count as laws only *ceteris paribus*, then we cannot expect more of the basic laws governing selection processes. However, these laws must be very general. Reference to genes is even too particular. All genes here on Earth are either DNA or RNA, but other molecules might well serve this same function. In fact, prions might well turn out to be gene-like molecules already existing here on Earth. In any case, one reason why Dawkins introduced the notion of a replicator is to make sure that selection processes are general enough to incorporate something very much like lawful regularities (for an extensive criticism of Dawkins, see Rose).

Given the requirement that the traditional laws of nature must be spatiotemporally unrestricted and monophyletic taxa are necessarily spatiotemporally localized, then it follows that monophyletic taxa cannot function in laws of nature. This is the reason why there can be no law of the aardvark. Few people would be all that upset about this conclusion for aardvarks, fruit flies and slime molds, but if *Homo sapiens* is a biological species, this conclusion follows for it as well. There can be no laws of human beings qua human beings. Unfortunately, many systems, both in science and outside of science, depend on *Homo sapiens* being a natural kind of some sort. Many of the social sciences turn on discovering 'universals', things that are true of all human beings and only human beings. For example, evolutionary psychologists insist that there is such a thing as the monomorphic mind, a belief that Rose finds particularly puzzling. If human beings evolve the way that other species do, then one should expect the human species to be genetically quite heterogeneous. Hence, it is at least possible for behavioral differences to be in some sense 'genetic'. However, these very biologists turn around and claim that numerous adaptations, such as a fear of snakes, are 'universal'. If so, how did all the genetic variability that surely played a role in the evolution of the human brain somehow get weeded out?

Evolutionary psychology

Several contributors to this volume, especially John Dupré, Rose and Nelkin, set their sights on evolutionary psychology and find it reductionistic of the worst sort. Like Rose, Dupré distinguishes between behavioral genetics and evolutionary psychology and also notes that these disciplines seem naturally antagonistic to one another in that 'evolutionary psychology is officially concerned with the search for human universals whereas behavior genetics is typically addressed to differences between humans'. However, they think that this hostility is largely illusory.

In his paper, Dupré proposes explaining the inadequacy of reductive explanations of human behavior in terms of single factors, in particular those at lower levels of analysis, e.g. explaining the behavior of people at the annual meeting of the Tunbridge Wells Contract Bridge Club in terms of the genes for metabolizing ethanol. Perhaps the effect of ethanol on people may explain some of the behavior in such social groups but not all by a country mile. Dupré reiterates the acknowledgment that for everything that counts as human behavior something must be going on in the nervous system, but such explanations are not always relevant and appropriate even when we have them. As the fire example above indicates, necessary conditions are not always explanatory.

Rose finds evolutionary psychologists scientifically deficient because they misunderstand evolution, development and neural function. He faults them for uncritically accepting the more theoretically abstract formulations of evolutionary theory produced during the modern synthesis. In addition, evolutionary psychologists reason too facilely from these highly abstract formulations to overly specific adaptationist claims. The weakness of such adaptationism is never more apparent than in the treatment of human beings, in particular the behavioral traits of human beings. These connections are not stated baldly in terms of genes coding for a particular behavior but leave room for environmental effects. Genes do not determine, they only dispose, possibly predispose. For example, primates turn out not to be innately fearful of snakes. The first time that a young primate sees a snake, it does not flee in terror. However, primates are predisposed to become afraid of snakes given only minor environmental cues from their congeners. However, Rose finds that these modified versions of gene-based evolution allot too much importance to genes (see also Griesemer). Selection occurs at a wide variety of levels of organization, not just at the genetic level (see also Hull).

Everyone knows that not all traits are adaptations, but Rose thinks that his fellow biologists need to be repeatedly reminded of this fact in order to neutralize their tendency toward adaptationist scenarios. Needless to say, at least some of these colleagues take offence at being reminded of the obvious. In addition, the distal stories preferred by evolutionary psychologists must be supplemented with the specification of more proximal causes. For example, a distal story can be told for stepfathers killing the children of their new wives more frequently than their own biological children, but more proximal causes such as the complexity of multiple relationships with their attendant economic and social insecurity may be even more relevant. Do rich, well-placed men kill their children, whether biological or adopted, less frequently than poorer, less prominent men? Within these numbers, is there a difference in murder rates between biological and adopted children?

Nelkin provides a litany of unwarranted reductionist claims about the implications of the innate predispositions of human beings to social policy. Most of the most infamous examples occurred in the past, e.g. the implications of craniometry, phrenology and eugenics for immigration and sterilization. However, she also sets out some more recent examples. With the power of hindsight, we can see the effects that reductionism has had on human beings in the past. Present-day examples are frequently not so obvious. Racism and sexism may have distal causes of the sort postulated by evolutionary biologists, but they also have even more significant proximal causes, and Nelkin argues that our attention should be directed at these modifiable proximal causes, in part because they are modifiable. Nelkin concentrates on the most egregious examples of the harm that reductionism has done. If such things as anti-reductionism, holism, pluralism, open immigration policies, the Great Society Programs of the 1960s, the democratic experiment in America which assumes the perfectibility of human beings, nurturing educational programs, a belief in free will and social causes as distinct from individual responsibility, have ever been misunderstood by the general public or done any harm, no one in this anthology mentions it. Reductionism may indeed lead to social problems but so do fundamentalist religions. In order to be properly 'pluralist', must Bible stories be taught in biology courses? As powerful and malevolent as such evolutionary psychologists as Steven Pinker, Leda Cosmides and John Tooby may well be, picture them lined up to do battle with the Taliban.

Reductionism and medicine

Elisabeth Lloyd, Tauber and Schaffner address the issue of reductionism in the practice of medicine. Tauber asserts that a fundamental demand of clinical practice is 'viewing and treating the patient in his biological entirety'. It is unlikely that any clinician would claim otherwise. It does no good to continue to remove a patient's appendix if he is already 'brain-dead'. Van Regenmortel makes a comparable claim about the immune system. Vaccination is an 'immunological intervention that is meaningful only in the context of the whole organism'. If all of the details of the incredibly complex workings of the immune system are spelled out but no mention is made to the effect that all these mechanisms have on the health of the organism, something desperately important has been left out.

However, Tauber goes on to argue that among the legitimate claims of holistic medicine is that the highest faculties of human beings must also be taken into account – the social, psychological, moral, and even spiritual aspects of human beings. A large percentage of physicians are likely to have some reservations about this higher calling. Such needs might well deserve to be met, but perhaps not by physicians, especially those currently being turned out by medical schools in developed countries. More strongly, given the contingencies of the settings in which medicine is practiced today, patients are lucky if they get their biological needs met adequately, let alone these higher needs. Tauber takes his position to be more than epistemological; it is also a moral imperative. This is how clinicians *should* treat their patients, whether they *can* or *do*.

Lloyd concurs and adds the patient's social entirety as well, citing a series of studies that show that ecological factors also matter, most surprisingly the income gradient of a society. What matters is not simply the difference between the richest and poorest people in some absolute sense, but the relative difference in their own society. People living in a relatively poor society can lead healthier lives than people living in a richer society if the difference between the richest and the poorest in their society is less. What really matters is how much poorer poor people are in a society relative to the richest people. However, Lloyd's later appeal to data drawn from primate studies might lead some to cry 'reductionism'. The human species is unique. No inferences can be made from other species, even primate species, to us.

Schaffner indicates the consequences that recent work in molecular biology has had on our hopes for understanding human illnesses and treating them. For example, genes responsible for cystic fibrosis turned out to have many more mutations than anyone had expected, and some of the genes that were thought to influence this disease did not because of differences in the genetic background of the host. Even though geneticists have discovered two genes related to breast cancer (BRCA1 and BRCA2), how much they increase the likelihood of developing breast cancer in women who have them and how to advise female patients who have a history of breast cancer is 'mind-numbingly complex'. Genetic knowledge is *knowledge*, but we are a long way from being able to use this information. Our increasing knowledge of the influence of genes on development seems only to replace one set of problems with another.

Disagreements versus differences in emphasis

In intellectual disputes, presenting the views of one's opponents sympathetically is not easy. Parody and defeat is too effective a strategy to reject totally. Dupré takes the debate over genetic reductionism to be:

> *. . . one of the more notoriously sterile exchanges in contemporary intellectual life. Both sides accuse the other of one or other versions of reductionism, and both generally claim that they, unlike their benighted opponents, really acknowledge a rich interactive conception of human life.*

Apart from insisting that he himself advocates a 'subtle and richly interactive conception of human life', Dupré does not go deeply into the intricacies of this debate. Carrying on in this same vein, Debru complains, 'Nowadays reductionism is often used as an insult which is uttered by people from various tendencies who have no real idea of biology, most of the time for ideological, social, or political reasons with little scientific relevance'. Michel Morange also distinguishes between 'simplistic reductionism' and the more sophisticated views being developed by molecular biologists today. It will be obvious that the term 'reductionism' is used in many different ways by the various authors. Shostak in particular uses terms like 'reductionism', 'monophyly' and 'cladistics' in a rather idiosyncratic manner.

The picture that emerges in this anthology is that what at first seems like hopeless disagreements turn out to be differences in emphasis. Everyone acknowledges that genes play an important role in the living world. Without genes, we would be in real trouble. However, certain scientists seem to place too much emphasis on genes, as if they were close to sufficient to understanding everything about living creatures. Reductionistic science is not all bad. It has been responsible for huge strides in our understanding of the world in which we live, but some phenomena do not lend themselves to this sort of investigation and for that reason they are commonly ignored. If reductionist methods won't do the trick, then some investigators conclude that the corresponding phenomena do not exist or are not worth investigating. The consensus view, however, leads to pluralism: both reductionist methods and a more holistic approach to biological complexity are required, depending on the questions being asked. It is undeniable that both approaches will continue to bring forth valuable biomedical knowledge.

References

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