Supplemental Material for Chapter 4, "The Principal Points in Dispute in the Evolution Controversy"

The Types of Arguments Employed in the Evolution Controversy

Version 1.0

Readers of material on evolution will rather quickly discover that there are certain types of arguments employed over and over to make critical points. It is reasonable to expect that only arguments and reasoning of the highest caliber would be used to establish conclusions and make the critical points upon which the explanatory power of the theory of evolution (and the positions of the other schools) depend. Unfortunately this is not the case, as several of the argument types are quite unequal to the task, and therefore the conclusions gleaned from them are of little value. Some other types may provide insight in certain cases. And still other types of arguments are sound and their conclusions can be relied upon. The principal types of arguments are:[*]

(1) Tautology
(2) Circular reasoning
(3) Analogy
(4) "Just-so" stories
(5) Incredulity
(6) Psychological plausibility
(7) Extrapolation
(8) Verbal dodges
(9) Combinatorial and probability
(10) Mathematical demonstration
(11) Strict logical deduction
(12) Inference to the best explanation
(13) "Hand-waving"
(14) Argument from authority
(15) Retreat into unknowability and untestability

We shall discuss them here, with examples. Though this treatment may seem a bit tedious to the reader, careful attention to the ideas discussed here will repay great dividends in terms of understanding the evolution controversy!

[*] This is not intended as a comprehensive list of all the types of arguments used in the evolution controversy, only a list of the more common ones.

1. Tautology

One type of fallacious argument or "inference" that is definitely excluded from science, for very good reason, is *tautology*. A tautology is a statement which is logically true, such as "All *A* are *A*", or "The man is either dead or alive". Such statements do not require any empirical knowledge for their truth value to be ascertained. In contrast, a statement such as "Nothing can travel faster than the speed of light" makes a statement which can be either true or false, that requires empirical investigation to determine which it is, and that conveys new (and useful) information. According to the dictionary, there are two senses in which "tautology" is used:

1. a.Needless repetition of the same sense in different words; redundancy. b. An instance of such repetition. 2. *Logic.* An empty or vacuous statement composed of simpler statements in a fashion that makes it logically true whether the simpler statements are factually true or false; for example, the statement *Either it will rain tomorrow or it will not rain tomorrow.*[1]

An example of (1) is "widow woman". The problem with tautologies is that they often *sound* impressive but *convey no actual information or knowledge*. The purpose of science, of course, is to do just that: convey new knowledge. "Evolution is survival of the fittest, and the fittest are those that survive" is an example of tautological reasoning. In branches of science other than evolution, use of tautology would bring scorn and ridicule on the speaker, and claiming that the most fundamental law or principle of the science was a tautology would not only call forth peals of laughter, but would ruin the speaker's reputation and cause him or her to be viewed as a comedian rather than a serious scientist. In the world of evolution, regrettably, this is not always the case.

Circular reasoning

Another type of argument that is the focus of much discussion in the evolution debate is *circular reasoning*. Circular reasoning occurs when uses assumption *A* to draw conclusion *B*, then uses *B* to justify *A*. The most common context for this is in discussions of dating methods. Creationists (and others) frequently accuse evolutionists of using circular reasoning as follows: fossils are dated on the basis of the rock formations in which they are found, and rock formations are then dated on the basis of the fossils they contain.[2] Dating methodology is, indeed, a non-trivial problem, one which has bothered many who have no connection with the evolution controversy. Breaking the circle obviously requires anchoring one of the statements to something outside, some other dating method (usually radiometric). This is discussed in the book in Chapters 5 and 6. For the present purposes, the point is that circular reasoning is not acceptable as a type of inference in science.

3. Argument from analogy

Arguments based on analogy are undoubtedly familiar to all readers, and in common use. They seek to exploit similarities in two situations, so as to induce the hearer to assent to a conclusion. In evolution, the most commonly used example is that of the "evolution" of man-made objects, which is supposed to be analogous to the evolution of natural plants and animals. The argument concludes that the latter evolved, because they followed a path analogous to that of the man-made objects. Consider the following version, which appears in a well-known anti-creationist book:

> Everything evolves in the sense of "descent with modifications," whether it be government policy, religion, sports cars, or organisms. The revolutionary fiberglass Corvette evolved from more mundane automotive ancestors in 1953…Other high points in the Corvette's evolutionary refinement include the 1962 model…in which the original 102-inch wheelbase is shortened to 98 inches and the new closed-coupe Stingray model was introduced; the 1968 model…[is] the forerunner of today's Corvette morphology, which emerged with removable roof panels; on…continues the stepwise refinements that have been accumulating since 1953. The point is that the Corvette evolved through a selection process acting on variations that resulted in a series of transitional forms and an endpoint rather distinct from the starting point. A similar process shapes the evolution of organisms.[3]

Now analogies in general are useful tools. They do not form the basis for valid arguments, but they do provide windows onto an unfamiliar landscape. That is their primary value: to allow us to learn about something *unfamiliar* by using our knowledge of something which is *familiar* to us. They are very commonly used, for example, in the study of history, where historians constantly look for analogies between current events and situations, and those of the past, in order to give us insight into where we are and what might happen in the future. Analogies and arguments from analogy do not provide proof of their conclusion, but only make it more or less probable, depending on how good the analogy is. Another type of argument should begin where the analogy leaves off.

Naturally, the main problem with analogies is that each is different, and there is no rule which allows us to gauge how far the analogy can be taken. For that, we must consider each on a case-by-case basis. That is why arguments by analogy are so unsatisfactory when used by themselves. In Berra's case, the reasoning is completely fallacious because the analogy breaks down at a critical point:

> Of course, every one of those Corvettes was designed by engineers. The Corvette sequence—like the sequence of Beethoven symphonies or the opinions of the United States Supreme Court—do not illustrate naturalistic evolution at all. It illustrates how intelligent designers will typically achieve their purpose by adding variations to a basic design plan. Above all, such sequences have no tendency whatever to support the claim that there is no need for a Creator, since blind natural forces can do the creating. On the contrary, they show that what biologists present as proof of "evolution" or "common ancestry" is just as likely to be evidence of common design.[4]

What is worse, Berra did not realize that the analogy could actually be used *against* evolution. If instead of conscious design decisions, fabricators and assembly line workers simply changed or modified parts randomly, hoping to improve the car, how many improved or even functional vehicles would emerge? Yet that would be a closer analogy to the biological case.

Had Berra restricted himself to saying that the analogy between Corvettes and biological organisms was a jumping-off point for biologists, who would then *investigate* whether natural processes could achieve the same kind of change wrought by intelligent automobile designers and engineers, all would be well. But to ignore the crucial difference between random changes and intelligently directed changes, and other significant differences (such as the fact that partially modified cars do not have to survive) is not acceptable scientific reasoning.

4. "Just-so" stories

Another gambit often found in discussions of evolution is the "just-so" story. These stories are hypothetical narratives, which are supposed to depict how some evolutionary sequence unfolded in prehistory. Such stories could serve a valuable function, name as a starting point for empirical investigations. Unfortunately, they are rarely used for that purpose. Rather, they are used as a *substitute for* that very investigation, and typically put forward as *proof* of the issue in question. This permits the author of the story to claim that any needed transformation or event could have come about, and probably did given enough time, without producing a shred of evidence. Consider the following examples:

> A small change in a word, such as adding an "x" to the end of it, will almost without fail destroy the whole meaning of the word; but a small change in a cow or a watch, such as decreasing slightly the length of a cow's hind legs or diminishing slightly the size of one cog in the watch, will not spell catastrophe. In such a way, all the cogs in a watch could change slightly, one at a time, eventually changing the entire configuration and sizes of the cogs, without destroying its function (presuming that watches can reproduce!). One can even imagine nonfunctional digital components being added until they finally begin to work, at which point the gears, springs, and cogs will fade into nothingness.[5]

Were a Creationist to make such an absurd argument, he or she would be pilloried by the Neo-Darwinists, and the statement held up to ridicule for years to come! If the author cared to run the experiment of changing the components of a mechanical watch in a random fashion, he would find out just how quickly the "catastrophe" would occur, especially if a change happened to occur in the escapement mechanism. It is also reassuring that the author can "imagine nonfunctional digital components being added until they finally begin to work". Perhaps the author can also imagine microprocessors forming spontaneously (one would be needed for the new digital watch)! It would doubtless be a cinch to get all 5 or 10 million transistors in the right place and connected properly! Unfortunately, science is not an exercise in pure imagination, but imagination and creative thought bound together in a highly disciplined fashion, and combined with experimental work.

Arguments such as this, which gloss over the most formidable difficulties, can be used to "prove" that *any* transformation, however complex and improbable, has taken place. Along these lines, development of the vertebrate eye is often taken as a touchstone, an example of something so complex that it could never have evolved through random mutations no matter how great a time span one wishes to consider. The problem is not merely the physical structure of the eye itself, but the associated image processing capability of the brain, and the ancillary nerve and muscle systems, all of which must be in place for any functionality to appear. For example, evolutionist Steven Rose discusses the development of the eye, basing himself on a computer model which purports to show that under certain assumptions, the task of getting an image-forming eye would take just 500,000 generations:

> Accepting these assumptions unquestionably requires something of an act of faith…but even so I see no problem with the general principle invoked here. In the classical Popperian sense, as we have seen, such evolutionary stories are unfalsifiable. *All that we can do, all that we are required to do, is offer plausible accounts of how a process may have occurred or a structure may have evolved,* in response to those who claim it is impossible on *a priori* grounds…Once again, as with genetic transmission, the problem of adaptation—at least as it confronted Darwin—is not an insoluble one. He surmised

> that it could be resolved, given enough evolutionary space and time, and he was surely right.[6] [italics added]

So here is how the logic goes: claims made on our side of the argument are unfalsifiable, so our opponents cannot refute them. Furthermore, it is unnecessary to do any real research to show that there are no barriers to the proposed transformation; all that we have to do is to make the story sound plausible. And finally, if any malcontents out there are still squawking, we'll silence them with the ultimate weapon: given enough time and space, anything can happen! (As it turns out, this assertion is dead wrong).

Is this science? It scarcely even qualifies as good rhetoric. Why wasn't the author called on it? How did it get past the Oxford University Press reviewers? If such shoddy reasoning, unjustified assertions, and long-range extrapolation had been written by an opponent of evolution, it would forever be cited as evidence of scientific incompetence. Curiously, Rose himself understands this in a related context, that of determining selective advantage, where many fantastic stories spring from creative minds:

> …the claims for selective advantage rest on fables, rather like Rudyard Kipling's famous *Just-So Stories* about 'How the elephant got its trunk' or 'The cat which walks by itself'. There is rarely any supportive evidence for such fables, and what data there are are subject to multiple interpretations…adaptionist just-so stories are rarely without alternative explanations.[7]

So why are we subjected to these worthless stories? The reader is advised to contemptuously dismiss them, and the evolution debate needs to be purged of them once and for all.

5. Argument from incredulity

Dawkins has described and criticized what he terms the "argument from incredulity", which is an argument against evolution based on the inability of the author to imagine a possible scenario or path by which some change might occur. Typically the changes in question involve substantial modification of function or morphology. In effect, "I can't imagine it, therefore it can't occur". Arguments of this type often include phrases such as, "It is inconceivable that…" or "We cannot envision a sequence of steps such that…" Dawkins believes that such arguments are of little value, as they comment on the author's imagination rather than the reality of the situation. This is correct: mere inability to imagine or envision a sequence of events does not imply that no such sequence is possible. However, *this fact does not relieve those proposing such changes from the responsibility of actually demonstrating the feasibility of the changes, in terms of probabilities of events and also conformity with known scientific laws*. On this aspect of the argument, Dawkins does not comment. Consider an example: Like the alchemists of old, I can propose that base metals be transformed into gold, even though I cannot supply a set of feasible steps. I can scorn those who criticize me for this inability, invoking the argument from incredulity; but like those alchemists, I will fail because I am ignorant of the composition of matter at the atomic level and the barriers it presents.

6. Argument from psychological plausibility (or substitution of plausibility for proof)

The line of reasoning Dawkins invokes for the "argument from incredulity" actually cuts two ways. The other direction, the other edge of the sword, is what we may term the "argument from psychological plausibility", which is an argument in favor of some type of change because the author can *imagine* it happening, can *imagine* a "plausible" path, regardless of the magnitude

of the change envisioned. In effect, "I can imagine it, therefore it can occur". In effect, such arguments *substitute plausibility for proof*. As such arguments are widespread, and well-known through Dawkins' book, *The Blind Watchmaker*, and other sources, we must analyze them carefully. Typically they include phrases such as "I can see no reason why this kind of change cannot continue indefinitely…", or "There is nothing to stop…". Dawkins himself uses this type of argument frequently. We have already seen the grave difficulties of such arguments when we examined the case of the early steam engines.

Neither the argument from incredulity nor the argument from psychological plausibility is conclusive; and if certainty is the goal, they are both worthless. So Dawkins is just as guilty of using poor arguments as his opponents. Nonetheless, since similar arguments are commonly used in everyday discourse, let examine them both in more detail to see what value, if any, they may have.

The weight that we give to such arguments in everyday discourse is a function of three things:

- The state of our knowledge about the subject
- The knowledge that the person propounding the argument has about the subject
- Any biases the person propounding the argument may have

Let us consider some examples. As of date of this writing (March, 2003), the maximum production speed of computer microprocessors is about 3 GHz. The speed of these processors has been doubling approximately every 18 months since the early 1970s (Moore's Law). This information is widely known. Therefore someone who is not an expert in microprocessor design could say, "I can see no reason why we can't make computers that run at 100 GHz". However, an expert in microprocessor design, or a solid-state physicist, might point out that there are much more formidable barriers to surmount in order to increase processor speed by another factor of 100, than there were to go from 10 MHz to 1 GHz. For example, the speed of light poses problems. At 1 GHz, the processor carries out an operation every 1 nanosecond. In one nanosecond, light travels 30 cm. Current microprocessors are about 1-2 cm on a side, so there is no problem. But at 100 GHz, light could only travel 3 mm. This poses a very serious size limitation on the processor, and imposes a very difficult heat dissipation requirement. There are, in addition, other difficulties having to do with the relatively small number of molecules of material involved in the fabrication of transistors and other components needed to operate at these speeds. This implies quantum mechanical limitations due to noise contamination of switching signals. There is also the difficulty of etching extremely fine lines on microprocessor dies. So, because of his or her domain knowledge in this case, and likely absence of bias, we would give the opinion of the microprocessor designer or solid state physicist considerable weight, much more than the non-expert. We would therefore draw as a reasonable conclusion that 100 GHz computers are not something we should be expecting on our desks in the foreseeable future.

In general, we will give arguments of the type in question a considerable degree of weight if we believe that the person advancing them is an expert in the relevant field, is not biased, and that there exists a considerable degree of knowledge in the area. Unfortunately, in the case of species transformation, empirical facts are in short supply, bias is available in large quantities, and the relevant mathematical, information theory, and systems arguments suggest

that nothing should be taken for granted—not a recipe the bodes well for either the argument from psychological plausibility.

7. Extrapolation

Extrapolation is the method of inference which looks at trends and mathematically or intuitively projects them beyond their current state. Typically the trends are historical, and are projected into the future, as is commonly done with stock prices, interest rates, or average gasoline consumption of cars. Trends can also be projected backward, if appropriate, to estimate the situation at some point in the past where there are no available data. Well-established mathematical techniques exist for doing such projection, such as regression analysis, and are readily available on spreadsheets and many pocket calculators. *What the mathematical methods do not tell us is how far into the future, if at all, such projections can be made*. This lesson was painfully learned by those investors who extrapolated the double-digit technology stock price increases of the late 1990s well into the future, and put their hard-earned money on some of those high-flying stocks. Typically, the shorter the range of the projection, and the more linear the phenomenon, the more likely extrapolation is to be valid. Long range extrapolation, especially extrapolation over orders of magnitude, is extremely risky and almost certain to be wrong. The problem is that unknown and unsuspected physical laws and barriers typically arise.

In case any readers are still doubtful about the misleading and unscientific nature of extrapolation, consider the following analogous situations, drawn from older and much less controversial branches of science. The steam engine, the first reciprocating man-made device harnessing the power of heat to do useful work, was invented at the end of the 17th century, and first used in an industrial context by Thomas Newcomen in 1712.[8] Early engines were used to pump water from mines. These engines were extremely inefficient in converting heat into useful work, and were gradually improved over the years. One can readily imagine an enthusiastic observer in the year 1800 waxing rhapsodic over the potential:

> I can see no limit to the ability of steam engines to produce work. The rapid improvements over the past 100 years lead us inexorably to believe that from ever small amounts of coal, more work can be achieved, until all of our mines have their water pumped by the smallest of boilers.

Unfortunately for this hypothetical observer, there were two obstacles in the way, unknown in the year 1800: the First and Second Laws of Thermodynamics. The First Law limits the amount of energy which can be obtained by burning a quantity of coal, and the Second Law the amount of that energy which can be actually converted into useful work. Still, we can imagine that these laws don't exist, and that we can build an engine to extract heat from the ocean and convert it into useful work (a so-called "perpetual motion machine of the second kind"), thereby changing the world's geopolitics. But imagining is about as far as we shall get!

A similar situation existed with respect to the performance of telescopes of a given size, at one time thought to be unlimited:

> During the two hundred years between the invention of the telescope and the final acceptance of the wave theory of light, people actually believed that there was no limit on optical quality. If optics were made of exquisite quality, the central spot would shrink in size—or so opticians thought. They must have agonized when their optical masterpieces, on which they had worked so diligently, still showed that disk surrounded by a system of rings. We now know that there is a fundamental limit to imaging…For a given telescope

> focal length, the central spot (called the *Airy disk*) decreases linearly in diameter for larger apertures.[9]

The limiting factor in optical systems, of which the Airy disk is an effect, is diffraction, a function of the size of the optical elements and the wavelength of light.

In evolution, extrapolation is most commonly invoked with respect to change over time, especially with respect to the ability of species to change into other species and ultimately into other taxonomic groups. Thus it is assumed that small changes in species due to the action of natural selection operating on a population over a relatively short time can be extrapolated to inter-species and arbitrarily larger changes over longer times. Since orders of magnitude are involved here, the matter requires very careful investigation to determine if the changes envisioned are even of the same *kind*. Consider the following example from Darwin himself, a master of the technique:[10]

> I can see no limit to the amount of change, to the beauty and complexity of the co-adaptations between all organic beings, one with another and with their physical conditions of life, which may have been effected in the long course of time through nature's power of selection, that is by the survival of the fittest.[11]

While it may be pleasing to know that Darwin couldn't see any limit, many others can. It is a matter to be decided by theoretical calculation and laboratory experiment, not intuition.

8. Claiming liabilities as assets

While this may sound more like an illicit accounting technique than a type of scientific argument, it is favorite rhetorical device of writers on evolution, especially those of the Neo-Darwinian school. The goal is to deflect attention from significant and often crucial gaps in knowledge of how complex transformations might have occurred by convincing the reader that there is no reason to doubt that they did. In this fashion, the writers are able to transform a *difficulty* of the theory into something *positive*—at least they are able to do so when the audience is unaware of the gambit. As Himmelfarb has pointed out,

> This procedure, by which one of the major difficulties of the theory [is] made to bear witness in its favor, can only be accounted for by a confusion in the meaning of "explain" between the sense in which facts are "explained" by a theory and the sense in which difficulties may be "explained away". It is the difference between compliant facts which lend themselves to the theory, and refractory ones which do not and can only be brought into submission by a more or less plausible excuse. By confounding the two, both orders of explanation, both orders of fact, [are] entered on the same side of the ledger, the credit side. [12]

Thus "difficulties" are surreptitiously converted into "assets". Fortunately, instances of this device are readily spotted because they nearly always begin with a disarming phrase such as, "I can see no reason that…", or "There is no reason to doubt that …" or "What is there to stop…" But, as is obvious, all such arguments—we use the term loosely—are worthless without supporting evidence (rarely forthcoming) and accordingly should be discarded without further ado. At times it is difficult to distinguish verbal dodges, arguments from psychological plausibility, and just plain old long-range extrapolation. Consider this interesting example of the technique:

> The Galeopithecus or so-called flying lemur, which formerly was ranked amongst bats, but is now believed to belong to the Insectivora….Although no graduated links of structure, fitted for gliding through the air, now connect the Galeopithecus with other Insectivora, yet there is no difficulty is supposing that such links formerly existed…"[13]

Commenting on this passage, Spetner points out the specious reasoning:

> From "there is no difficulty in supposing", [Darwin] went on to lead the reader into agreeing that it *probably* happened, and finally he assumes the reader goes along with him in agreeing that it did indeed happen that way. His arguments, however, consist in no more than "I can see no difficulty…", to "there is no difficulty in supposing…", "nor can I see any insuperable difficulty in further believing…" which he parlays up to "it is conceivable that …" and to "we might expect that …". What started out as a difficulty became, in the end, another "demonstration" of the power of natural selection….Interestingly enough, even today, the origin of the bats is not found in the fossil record.[14]

Readers might think that we have made up the following example as a caricature, were it not for the fact that they can find it themselves in the public domain:

> Just look at the different varieties of dogs that exist today, and ask whether a Chihuahua and St. Bernard can be connected only by saltations? If such profound change can occur and speciation does…occur, then what is to theoretically stop a remote ancestor from evolving into all of the primates? What is theoretically to stop an ancient ungulate from evolving into a whale, or an ancient fish into an amphibian?[15]

A better question, perhaps, is "What is theoretically to start it, and what to continue it?" Where does the burden of proof lie? It lies on the person making the assertion. Here too the verbal dodge melds into an argument from extrapolation, and rather long-range extrapolation at that.

On occasion the author will dispense with the disarming phase and just state the gap in bald terms, albeit positively so that careless readers may still accept it in the belief, presumably, that anything so outrageous must be true or it would never have been committed to print:

> Despite our ignorance of the overwhelming majority of life forms which exist on Earth today (indeed, most biochemical and genetic generalizations are still derived from just three organisms: the rat, the fruit fly, and the common gut bug *Escherichia coli*), and our inability to do more than offer informed speculations about the processes that have given rise to them over the past 4 billion years, we biologists are beginning to lay claims to universal knowledge of what life is, how it emerged, and how it works…Biology also makes claims as to who we are, about the forces that shape the deepest aspects of our personalities, and even about our purposes here on Earth. The claims of the science have become so strong as to seem no longer a matter for debate: they are now the natural way to view the living world.[16]

Here we see an astonishing example of what Himmelfarb pointed out so clearly, in this case, an effort to transform ignorance of much of life's history into an asset. But it won't work with anyone alerted to the technique. Either the author has some proof or demonstration which can be offered for consideration, or he does not. Once again, reader beware!

9. Combinatorial and probability

Combinatorial and probability arguments seek to establish a particular conclusion on the strength of some extremely high or low probability. "Combinatorial" in this context refers to the calculation of combinations and permutations.* Typically one estimates the total number of things which can possible occur, and then compares it with the number of things which actually occurred or which need to occur. As a trivial example, one may wish to know the probability of tossing three heads in a row with a fair coin. There are eight possible sequences for such a toss: HHH, HHT, HTH, HTT, THH, THT, TTH, and TTT. Only one meets the criterion, so the probability is 1 in 8 or 0.125. On average, once out of eight times one will toss three heads. Such arguments can be useful *if fairly accurate bounds can be placed on the events which can occur*. These bounds, however, are usually difficult to estimate accurately because of the many assumptions which go into them for realistic problems. Typically combinatorial arguments are used by opponents of evolution to infer that chance formation of molecules with the sequences required for biological activity are so small as to render the event impossible. Proponents of evolution, on the other hand, argue that, given enough time, *anything* can happen by chance.

Unfortunately many of those using combinatorial arguments stumble because they do not realize how fast the numbers can grow; the reader is cautioned that numbers obtained even in relatively simple cases can be astronomically large (or infinitesimally small). Use of such arguments in the general context of evolution dates back at least to David Hume, who also has the distinction of being the first to stumble over the arguments for this very reason. In his *Dialogues Concerning Natural Religion* (1779), Hume sought to discredit the well-known argument from design (for the existence of God) by claiming that any apparently "designed" object could come about by chance, given enough time. Hume, however, significantly underestimated the complexity of even simple things, and of course had no inkling of the complexity of biological molecules. A biological molecule consisting of 200 amino acids, which must be arranged in the correct order, is rather unlikely to form by chance. Given that each of the 200 positions can have any one of 20 different amino acids, the total number of possible arrangements of 200 such amino acids is $20^{200} \sim 10^{260}$ (that is, 10 followed by 260 zeros—an inconceivably large number). If such a molecule were to form, with a particular order, its chance of forming is thus 1 in 10^{260}.

To put this into context, we may estimate the maximum number of "events" which may have happened in the lifetime of the universe as follows: The shortest time interval that has any physical meaning, i.e., the shortest time in which something can "happen", is referred to as "Planck time", 1.35×10^{-43} seconds.[17] The estimated age of the universe is about 15 billion years $= 4.73 \times 10^{17}$ seconds. The number of particles (baryons) in the universe is estimated to be on the order of 10^{80}. This yields, for the maximum number of "events" in the history of the universe,

$$10^{80} \times 4.73 \times 10^{17} / 1.35 \times 10^{-43} = 3.5 \times 10^{141}$$

So even if we make the absurd assumption that every particle in the universe were generating proteins of length 200 amino acids, at the rate of one per Planck time since its origin, we would still fall short of making the generation of any given sequence probable by more than 260-141 ~ 120 orders of magnitude. Obviously, biological molecules do not form this way.[18] Any

* Its scope in modern mathematics is broader, usually encompassing graph theory and other areas.

argument (and they are rather common) containing the phrase "Given enough time…" should be regarded with extreme suspicion.

10. Mathematical demonstration

Mathematical demonstrations start from mathematical formulations of scientific hypotheses, and proceed to deduce consequences from them. For example, from Newton's second law $F=ma$, and Maxwell's equations of electrodynamics, it is possible to deduce that an electron injected transversely into a uniform magnetic field will move in a circle. From those same Maxwell equations, it is possible to deduce the laws of optics. And in genetics, from Mendel's laws it is possible to deduce the probability of dominant and recessive characteristics appearing in offspring, knowing the boundary conditions (the alleles present in the parents).

11. Strict logical deduction

This, of course, is the "gold standard" for arguments: one starts with premises accepted by all, and then deduces by means of standard logical techniques, a desired conclusion. It is of course the staple of mathematics, and is used commonly in science as well. As a simple example, consider the following:

> According to the particle theory of matter, no interference patterns should appear when particles are sent through two closely spaced slots. Such a pattern is in fact observed. Therefore the particle theory of matter is in error.

An example from evolution, actually from Darwin himself, is also straightforward:

> There are no hard-and-fast barriers between species. Species are always changing in response to selection pressures. Therefore a large part of the fossil record should consist of transitional forms.

Such reasoning is of the highest importance to science because of its clarity and the lack of ambiguity in what it says or predicts.

12. Inference to the best explanation

Another type of argument which is important in science, but which has been recognized only recently, is the *inference to the best explanation*. This type of reasoning arises when several different and mutually incompatible explanations of some observed phenomenon can be made, and a choice must be made as none of them can be excluded on the basis of available evidence. At some level, all of science is based on such inferences to the best explanation, as competing theories always exist. For example, the heliocentric and geocentric theories can both "explain" observed celestial phenomena such as the movements of the sun, moon, and planets; but the latter was rejected in the 16th century as too cumbersome and unwieldy, with the constant need of *ad hoc* assumptions to explain new or more detailed observations. In some cases, the weight of a particular experiment is sufficient to make the selection of the best explanation rather easy. An example is the case of competing theories of heat in the 19th century. Some believed that heat was a fluid which flowed from hot to cold bodies. Others believed that no such fluid existed, and that heat arose from mechanical motion. Count Rumford carried out the definitive experiment utilizing canon-boring machines in 1798.[19] A more modern example—and a controversy which still rages though it is slowly dying down—concerns the deterministic nature of reality.

According to the Copenhagen school, the uncertainties and corresponding lack of determinism in nature revealed by quantum mechanics, and expressed through Heisenberg's Uncertainty Principle, are rooted in the nature of matter and energy; according to the competing school championed by Einstein and deBroglie, these uncertainties reflect our measuring ability but not the nature of reality itself, and there are "hidden parameters" which, if found, would reintroduce determinism into physics. For many years this matter was argued vehemently by both sides, with no clear resolution. But in 1982, an experiment was performed by Alain Aspect and his group at the University of Paris which indicated that the Copenhagen school was correct, thus giving weight to their position as the best explanation. Adherents of the opposing school did not give up, but have been losing ground ever since. In the case of evolution, as we shall see, the use of inference to the best explanation becomes very important indeed.

13. "Hand waving" arguments

It is perhaps a bit presumptive to include this type of "argument" in the august company of some of the others discussed in this chapter; but because hand-waving is such a mainstay in the evolution wars, we must discuss it in some detail. The adjectival phrase "hand waving" originates from the propensity of certain professors and others to literally wave their hands in order to distract attention from gaps in their arguments, and pretend that they have actually made a case for their position. The *American Heritage Dictionary* definition of "hand waving" is, "usually insubstantial words or actions intended to convince or impress." So why, when addressing a serious scientific question, would any resort to "hand waving" arguments? Surely they are the antithesis of science and even of rationality in general.

The answer, of course, is that in any ordinary scientific discussion, say about the Theory of Relativity, or the efficacy of a drug in combating a disease, hand waving arguments would immediately be ruled off the table, as they are completely worthless. In the often surreal world of evolution discussions, however, they are frequently invoked when the speaker or writer needs to make an essential point, and does not have the required evidence to do so. As this seems to occur on a fairly regular basis, we find hand waving arguments invoked rather commonly. Once again, the message is, "Reader beware!"

14. Argument from authority

The "argument from authority" invokes a presumed authority on a topic in order to dismiss some criticism or reasoning as ill-informed and/or missing or misunderstanding the point. It is often regarded as the weakest form of argument; but people are frequently intimidated by subjects they do not understand, and are willing to accept the opinion of authorities uncritically. In the case of science this is usually a prudent course of action because the "authorities" can generally back up their claims with direct observational and experimental data. Anyone who wishes to challenge the Theory of Relativity, for example, will quickly discover how much support can be brought to bear by an authority such as MIT or CalTech. Only in the case of evolution does the appeal to authority seem to break down, for the reasons discussed in this book (confusion of facts with explanations, use of faked and doctored evidence, failure to make testable predictions, etc.). And what is much worse, the authorities (and their legal allies) have a proclivity for trying to squelch debate about evolution by impugning the motives of its critics rather than addressing the merits of their case—something quite at variance with the usual desire of teachers to encourage such questioning so as to sharpen student skills and increase the depth of their knowledge.[20] The fact that open debate about of subject of such

great cultural import is not encouraged is itself another index of just how ideological the whole dispute has become. And in the Creationist school, a similar situation obtains because of the boundary condition that all theories must conform to the Biblical time frame and sequence of events. There is no debate about the authority of the Bible and its literal interpretation, and conflicting evidence is dismissed or reinterpreted as necessary. However, the Creationists are at least forthright about the authority issue, and do not debate their adversaries on the basis of it. In general, because of the foregoing problems, and the melding of science, philosophy, and theology in all schools of thought, argument from authority is of little value on any side. *Ask the authorities for the facts, the evidence, and the predictions, please!*

15. Retreat into unknowability and untestability

Some readers may decide that this type of argument is "the last refuge of scoundrels."[21] When confronted with an unsolvable or particularly vexing problem, the disputant invokes the "retreat into unknowability and untestability" argument, asserting that some *different* set of conditions existed in the past. These conditions no longer exist and cannot now be replicated, but account for the difficulty the disputant is facing. We may cite two examples. First is the argument employed by some Creationists to resolve the problem of the apparent age of the earth as manifested by radiometric dating techniques. According to this argument, certain physical constants changed or were different at some earlier time, resulting in dramatic acceleration of nuclear processes and thus effectively invalidating the radiometric techniques. Second is the response of Neo-Darwinians when confronted with biological molecules, such as *histone 4*, which are "all or nothing", i.e., they cannot function unless correctly formed. These molecules cannot have evolved because any difference from their present structure would render them dysfunctional, effectively disrupting critical cellular processes such as replication. To this, the Neo-Darwinian replies yes, that is the case now; but at some earlier time, it was not so, and there was then a possible evolutionary pathway.

Now, what is so disconcerting—not to say exasperating—about such arguments is the fact that they *could* be correct, so the disputant cannot be accused of making a demonstrably false statement. But there is no way to prove or even investigate them, as they invoke essentially unknowable past events. The only evidence for them is that their contrary will destroy the disputant's entire position, so they *have to be true*, at least in his view.[22] We leave it to the reader to decide for him- or herself the acceptability of such arguments!

It is hoped that this review of the types of arguments used in scientific (and not so scientific) discussions of evolution will alert the reader to the need for vigilance whenever he or she reads works on the subject. All claims should be backed up by facts, reasoning must be carefully analyzed to determine if it really supports the conclusion claimed, and any type of extrapolation must be treated with suspicion.

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[1] *American Heritage Dictionary*, 3rd edition, electronic version, Houghton-Mifflin Company, 1992.
[2] Cf. AiG-US Weekly News, 3 March 2003,
[3] Tim M. Berra, *Evolution and the Myth of Creationism*, Stanford: Stanford University Press, 1990, pp. 118-119.
[4] Phillip Johnson, *Defeating Darwinism by Opening Minds*, Downer's Grove, IL: Intervarsity Press, 1997, p. 63.
[5] Mark I. Vuletic, review of Michael Denton's *Evolution: A Theory in Crisis*, available at the Talkorigins website, http://www.talkorigins.org/faqs/denton.

[6] Steven Rose, *Lifelines, Biology Beyond Determinism*, Oxford: Oxford University Press, 1998, p. 194.
[7] Rose, *op. cit.*, p. 234.
[8] D. S. L. Cardwell, *From Watt to Clausius. The Rise of Thermodynamics in the Early Industrial Age*, Ithica, NY: Cornell University Press, 1971, p. 13-15.
[9] Suiter, Harold Richard, *Star Testing Astronomical Telescopes*, Richmond, VA: Willmann-Bell, 1994, p. 11.
[10] Gertrude Himmelfarb, *Darwin and the Darwinian Revolution*, Garden City: Doubleday, 1962, p. 334.
[11] Darwin, *Origin of the Species*, 1872 edition, reprint, New York: Random House, 1993, p. 141
[12] Gertrude Himmelfarb, *Darwin and the Darwinian Revolution*, Garden City: Doubleday, 1962, p. 334.
[13] Darwin, *Origin of Species*, Sixth Edition, 1872, Reprint by Dutton, New York: 1963, p. 182ff.
[14] Lee Spetner, *Not By Chance!*, New York: Judaica Press, 1997, p. 84.
[15] Mark I. Vuletic, review of Michael Denton's *Evolution: A Theory in Crisis*, available at the Talkorigins website, http://www.talkorigins.org/faqs/denton.
[16] Steven Rose, *Lifelines, Biology Beyond Determinism*, Oxford: Oxford University Press, 1998, p. 4-5.
[17] Paul A. Tipler, *Physics for Scientists and Engineers*, New York: Worth, 1991, p. 1420.
[18] This fact has been noted by many writers, some of whom are definitely not in the Creationist or ID schools. See G. Nicolis and I. Prigigine, *Self-Organization in Nonequilibrium Systems*, New York: Wiley, 1977, p. 23.
[19] See http://dbhs.wvusd.k12.ca.us/webdocs/Chem-History/Rumford-1798.html.
[20] See Johnson, *op cit.*, chapters 2 and 3.
[21] With apologies to Samuel Johnson for appropriating his famous phrase.
[22] Logically, the argument works like this: if p is the statement that the theory of evolution is true, and q the statement in question, e.g. "histone 4 formed under different conditions in the past", we have $\sim q \supset \sim p$, p, therefore $\sim\sim q$ or q, by modus tollens. Of course, it would be easier to argue $p \supset q$, p, therefore q by modus ponens.