

EXPERT REPORT FROM KEVIN PADIAN, PALEONTOLOGIST

A. Identification

I am a Professor in the Department of Integrative Biology and a Curator in the Museum of Paleontology at the University of California, Berkeley, where I have been for 25 years. I have a bachelors' degree in Natural Science and a Masters of Arts in Teaching degree from Colgate University, and a Ph.D. from Yale, where I did my dissertation on the structure, functional morphology, and evolution of flight of pterosaurs (flying reptiles from the age of dinosaurs). I was principally trained in evolutionary theory, paleontology, zoology, and the history of science. I am the author of nearly 100 peer-reviewed papers (some co-authored) and several books that span topics from the evolution of dinosaurs to the development of evolutionary thought. I have been an officer or committee chair or member for prominent scientific societies, and a member of the editorial boards of many of the major journals in my field. I have also been active in the improvement and advocacy of science education, notably in my capacity as a principal author and editor of the 1990 *California Science Framework K-12* and as the longtime President of the National Center for Science Education. I have served as a Distinguished Lecturer for Sigma Xi (the Scientific Research Society for North America), awarded to about two dozen people per year in all branches of science, science education, technology, and science policy. I have been a visiting professor at the Collège de France (an elite body of the most distinguished 50 or so scholars in France) and at the National Museum of Natural History in Paris, and I am the recipient of the 2003 Carl Sagan Award for the popularization of science.

B. Paleontology as a science

Paleontology is the study of past life, its evolution, and its climates. Paleontologists find and describe new kinds of fossil life, integrate new finds with previous knowledge, and investigate questions about how life has changed through time. Field work, museum work, and laboratory work are three approaches to understanding fossilized remains, and many paleontologists take all three approaches. To ask intelligent questions and determine reasonable answers requires knowledge of fossils, of comparative anatomy, of geology, systematics, physiology, ecology, functional morphology, and quantitative methods of analyzing data, among other fields. Not all paleontologists concentrate on or do research in all these fields. The point is that expertise in these fields is required in order to come up with knowledgeable answers.

The questions that paleontologists ask have to do with the diversity of life through time. What are the relationships among groups of fossil organisms? When did the different groups first appear, how did they diversify, and how and when did they become extinct? What adaptations did they evolve, and what opportunities in their environment did they take advantage of? What is the difference between normal extinctions and mass extinctions, besides just greater numbers? What environmental changes affect the diversity and diversification of life, and why? How do the mechanisms of developmental biology help us to explain the morphological diversification of structures in plant and animal evolution? How do structures change in lineages as new behaviors and functions emerge? What can knowledge about the life of the past tell us about the present, and vice versa?

The answers to these and many other questions cannot be approached without the input of paleontology, and many of them can only be answered by fossil evidence. Molecular biology has produced tremendously powerful tools to compare the DNA sequences of all manner of

living organisms (and a few extinct ones), and so help to derive their evolutionary relationships. However, molecular systematics can say nothing about the relationships or roles of fossil organisms to each other, or to living lineages. For example, several recent molecular analyses agree that whales and hippos are each other's closest relatives (Boisserie et al., 2005). From this conclusion, some authors have suggested that because both kinds of animals spend time in the water, their common ancestors would have been aquatic. Only the fossil record could show that this inference is incorrect. The first hippos were terrestrial, not amphibious; they evolved from an extinct group called anthracotheres, and they did not appear until the late Oligocene or early Miocene (Carroll, 1989; Boisserie et al., 2005). Whales were fully aquatic by the late Eocene, some 35 million years before the first hippos evolved, and they too evolved from animals that were entirely terrestrial (Thewissen, 1998; Padian and Angielczyk, 1995 and in press). Therefore hippos and whales, even if they are each others' closest relatives among living animals, did not have a common ancestor that lived in the water, but that was terrestrial. Only paleontological research and materials could demonstrate this. And this is only one example. A fuller explanation of the role of paleontology in evolutionary biology requires some historical perspective.

C. Paleontology and History

In the early 1800s, before the idea of evolution was accepted in France, England, or other European countries, people of typical religious conviction, interested in what they could learn from natural history, assembled collections of rocks and fossils from the various geological strata of their regions (Bowler, 1984). Independently, these people began to construct maps of their countries, with distinct areas that represented the outcropping of certain kinds of rocks and the fossils that they contained. William Smith in England, and Cuvier & Brongniart (and later d'Orbigny) in France, were only a few of the pioneers. These men pieced together columns of the geologic record from geographically separate but geologically similar rocks in close proximity, and so stretched their schemes across large tracts of land. They were the first to see the progression of fossil faunas and floras through the geologic column, which they correctly reasoned corresponded to prehistoric time, recorded in the rocks. They made no assumptions about evolution at that point, though the idea had been 'in the air' for decades. They simply noted the progression of fossils through time. They saw that the lower in the rock column they went, the less the fossil remains looked like plants and animals of today. And they saw that some more derived forms such as mammals did not appear until well after the rocks that held the first invertebrates, the first jawed vertebrates, the first vertebrates to walk on land, and so forth. This is quite evident, for example, in the textbook *Palaeontology* that Richard Owen, the most eminent Victorian vertebrate paleontologist and zoologist, published in 1860, just months after Darwin released *The Origin of Species*; and Owen was not at all a Darwinian transmutationist. None of this has been controversial since before Queen Victoria assumed the throne; but the authors of *Of Pandas and People*, among other "Intelligent Design" proponents and anti-evolutionists, pretend that the debate is a lively one, and that students should keep open minds about the whole thing.

Darwin was not the first to propose the concept of evolution; he was preceded by one century (Buffon and later Lamarck in France) and even two centuries (Hooke in England). But his evidence persuaded a great many educated people to accept evolution as an explanation for the diversification of life, even though his book was largely about the mechanism of natural selection (Hull, 1973). He used artificial selection to serve as an analogy for natural selection, and he was successful. That is what his book was about. Darwin was not talking about how major new adaptive changes took place; he was talking about how minor variations could be

selected upon by natural forces to produce heritable evolutionary change. Darwin reasoned that the kinds of changes that have occurred to separate related species, given enough time and the action of natural selection and other forces, would produce the diversity of life that we see today. He also saw that selective extinction through time would eliminate the vast majority of common ancestors and forms that had features transitional between those direct ancestors and forms that live today. We should not expect to see many “transitional forms” between “major groups,” because most such forms would quickly be replaced by even better adapted ones, if opportunities for diversification and the influence of natural selection persisted. Darwin knew that the progression of fossils in the record supported his general theory of the evolution and diversification of life, and he wrote as much; but he had no need to defend paleontology in order to make his main point. He was really talking about the “baby steps” of evolution, how change occurs to lead to the emergence of new species. He made only the most passing references to how new major adaptive types might emerge, though he was convinced that this would occur naturally in the course of time as new species and lineages diverged from previously existing ones. His main concern, however, was with the mechanism of natural selection, which cannot be observed directly in the fossil record; so people should not confuse his main argument about natural selection with his ideas about the evolution of life.

The statements in the paragraph above form the essence of most of what would be called Darwinism (Mayr, 1983). Darwinism is not just about natural selection; Darwin did not think that natural selection was the only direction-giving force in evolution. Nor did he think that random forces were important in evolution (note that selection is the opposite of random). Darwin was not an atheist; Darwinians are not atheists. They do not think that “random forces” are responsible for the evolution of life. Natural forces are not necessarily “random,” and what scientists mean by the word differs from its use in popular parlance, which accounts for a great deal of misunderstanding that is exploited by anti-evolutionists. Again, selection is the opposite of randomness. The fossil record shows a great many orderly patterns through time (Sepkoski, 2002), and the patterns of diversification of groups of organisms derived from molecular phylogenetic analyses correlate very well with the patterns seen in the fossil record (Benton and Hitchin, 1997). The fossil record provides strong support for evolution, and it has since the mid-1800s.

D. “Intelligent Design Creationism”

“Intelligent Design,” more properly known as Intelligent Design Creationism (IDC), is an ideologically motivated, sociopolitical movement with no science content (Pennock, 1999; Forrest and Gross, 2004; Shanks, 2004; Young and Edis, 2004; Scott, 2004). The jargon of science is used by its proponents, some of which have degrees in some kind of science, and they invoke a smoke-and-mirrors pantomime of scientific logic, but there is no scientific substance to this rhetoric. This is the published view of, among others, the **American Association for the Advancement of Science** (<http://www.aaas.org/news/releases/2002/1106id2.shtml>), the **National Academy of Science** (<http://www.nap.edu/catalog/5787.html>; see also <http://www.nap.edu/catalog/6024.html>), the **National Association of Biology Teachers** (http://www.nabt.org/sub/position_statements/evolution.asp), the **National Science Teachers’ Association** (<http://www.nsta.org/positionstatement&psid=10>),

President George W. Bush's Science Advisor, John Marburger
(<http://www.prospect.org/web/page.wv?section=root&name=ViewWeb&articleId=9216>),
and many other scientific authorities and organizations
(see for example <http://www.ncseweb.org/article.asp?category=2>).

The IDC proponents have no expertise in the subjects that they profess related to the science of evolution. None of them has expertise in the fields that are essential to the science of paleontology, described above in Section B. The "scientific" constructs of IDC have no scientific basis, and the rest of its published corpus comprises the same criticisms of evolutionary biology that have been the stock in trade of more traditional religiously motivated anti-evolutionists for decades.

The precepts of IDC fail on every count: (1) their criticisms of evolutionary biology are incorrect; (2) even if their criticisms were true, IDC would not therefore be substantiated by default; (3) there is no empirical evidence for IDC; (4) IDC proponents are not "doing" science in any professional sense; (5) scientific societies and authorities have roundly and unanimously criticized IDC because it has no scientific basis, and because its proponents have made no effort to test it as real science must be tested.

If IDC were presented in science classes as if it were science, (1) students would completely misapprehend the structure and logic of science; (2) their understanding of evolutionary biology would be deficient and misinformed, and their "training" in science would be significantly inferior to that of other school districts, and to schools in other countries; and (3) taxpayer dollars would be wasted.

I will address the challenges that IDC has posed to paleontology, the study of the fossil record and the evolution of life. To do so, I will first describe how IDC has defined itself "scientifically," and then deal with the ramifications of its challenges for paleontology.

E. The scientific "substance" of IDC

IDC rests on two propositions that are supposed to be testable scientifically. The first is "irreducible complexity," and the second is "specified complexity."

1. "Irreducible complexity" is a very old idea, dating back at least to the father of "Natural Theology", William Paley, an English theologian of the late 18th Century. It states, essentially, that if you discover a structure or function that is too complex for your imagination to conceive that it could have been assembled piece by piece, then it must have been created, presumably by a supernatural force (Paley, 1800). From this deduction you may conclude that a divine Creator exists, and this is what IDC would encourage teachers to tell their students (other experts will address this point). This interventionist line of reasoning was abandoned by mainstream Christian theologians during the 19th Century; whatever they may think now, they do not promote "Intelligent Design."

Biologists agree that many biological structures would not perform certain functions if one or more of their important components were absent. But this does not mean that they could not evolve in a sequence, at each stage of which the combination of characters was perfectly functional for some purpose. In fact, we have numerous examples of this from the fossil record and from phylogenetic studies of living organisms. The notion of "irreducible complexity" may work for manmade devices such as watches, but it has never been established as a biological concept. Therefore it has no standing in science. Furthermore, without knowing the ancestors

(which IDC proponents will not admit), it is impossible to test this notion. One cannot simply excise organs from a living organism and expect it to function, because experimental mutilation does not simulate an ancestral state.

The modern IDC version of Paley's rhetoric is promulgated by IDC proponent Michael Behe (e.g., 1996), a fellow of the Discovery Institute (DI) and a biochemist with no apparent expertise or credentials in evolutionary biology. Behe has never, as far as I can tell, subjected his ideas on "irreducible complexity" to scientific peer review in journals that focus on evolutionary biology. He has used, *inter alia*, the bacterial flagellum as an example of a structure that would not work if any of its 50 or more components were absent. However, as other experts will testify, some 20 of those components may be absent without detriment to the flagellar function, although the flagella are no longer effectively guiding the bacterium. Furthermore, related bacteria possess fewer than 30 of those flagellar components, and the organisms are still viable, thereby falsifying Behe's claims. However, the function of the flagella in these bacteria is no longer in propulsion, but in protein secretion. The reasonable conclusion is that the structures we call flagella at first served the secretory purpose (and before this, perhaps other purposes), and only later changed behaviorally and structurally to work in propulsion. Behe and other IDC proponents fail to grasp the central evolutionary principle of *exaptation*: that a structure that initially is developed in the service of one function may be modified to serve a completely different function. The IDC philosophy of "irreducible complexity" holds that it is impossible for structures to become modified and to acquire new functions, but the data of paleontology and other evolutionary lines of evidence falsify this claim. It is impossible to make sense of the paleontological record if one accepts the unsubstantiated notion of "irreducible complexity."

The questions of "irreducible complexity" involve what IDC proponents (incorrectly) characterize as **macroevolution** (major changes that separate distinct groups of organisms, in their view), which they say (without evidence from the fossil record or any other source) is caused by processes that are distinctly different from the processes of change that we see in populations, which they call **microevolution** (Davis and Kenyon, 1993). (In their view, "macroevolution" cannot be caused by known evolutionary processes, so we must look to an Intelligent Designer for intervention.) IDC-brand "macroevolution" directly impinges upon the knowledge of the evolution of major groups and their adaptations that we have from the fossil record, so it is quite germane to the study of paleontology.

The fossil record provides one of the most direct challenges to IDC's central precept of "irreducible complexity." Since the first reception of Darwin's theory in the 1860s, critics of evolution have attacked the notion that complex structures could evolve piece by piece. They have asked, as St. George Mivart did in the 1860s, "of what good is half a wing?" And this catchphrase could be used effectively in science education to promote the notion of IDC (though it would be erroneous, inasmuch as aspersion cast on one idea is not logically or empirically a support for an alternative).

In fact, it turns out that there are plenty of uses for half a wing, and these are supported by the fossil record. Bird wings are composed of feathers, which we have traditionally thought a hallmark of birds. It is quite clear that birds evolved from a group of small theropod (carnivorous) dinosaurs sometime in the Late or Late Middle Jurassic (Padian and Chiappe, 1998a). For more than a decade, new discoveries in China have shown that the small theropod dinosaurs most closely related to birds already possessed feathers, but these animals were too big to fly with them (and the feathers too small; see Padian and Chiappe 1998a, b, and Prum and Williamson, 2001). Direct fossil evidence shows us that the first feathers were hairlike and filamentous, then branched, then organized in a planar structure with a central stalk (rachis) and vanes, then were reinforced by barbs and barbules. Some other feather types present in the

close dinosaurian relatives of birds did not persist in birds (Padian et al., 2001). These structural changes in the evolution of feathers are paralleled by the ontogenetic development of feathers in the skin of embryonic birds (Prum and Williamson, 2001). The rudimentary development of hairlike feathers indicates *prima facie* a function in insulation; some other simple feathers have banded color patterns, indicating a function in display or camouflage (or both); fossils of nesting theropods have the fingers spread over the eggs, and closely related theropods with long feathers preserved on their long fingers show that such feathers would have shaded the eggs. This evidence demonstrates at least three other indisputable functions of feathers before flight evolved. Such an "incomplete" wing could also conceivably be used for trapping small prey such as insects, for diverting attention from a potential predator during escape, and for assisting in turning and leaping in a ground-running animal. Such incomplete wings have also been experimentally proven to be of use to hatchling birds in creating a downward thrust that holds them to trunks and other vertical surfaces that they run up in order to escape danger (Dial, 2003).

If schoolchildren were taught according to IDC precepts, they would learn that a complex structure like a wing would be useless until it was fully formed, and that this is therefore evidence for the miraculous intervention of a "master intellect" or a Creator. (This last precept would not necessarily be taught directly, but it would be directly implied, and is directly stated in suggested "supplementary materials" such as *Of Pandas and People*.) San Francisco State University biochemist Dean Kenyon, one of the authors of *Pandas*, stated in his affidavit submitted in *Edwards v. Aguillard*, "... the gap between reptiles and birds will remain unbridged until such time as a fossil reptile with the beginnings of feathers may be found." We have at least half a dozen such species of animals now. Forty years ago, we had much less direct information about the structure and function of early feathers and incipient wings, but today our picture is much different. Given this new information, a science teacher could explain exactly what good "half a wing" is. Just because we do not have enough scientific evidence at a given time to decide a given question does not mean that we will never have it, or that the question is insoluble by the means of natural science.

In this respect, "irreducible complexity," like other parts of IDC's approach, is what we call in science education a "science stopper." If your answer to a scientific question is that some sort of Intelligent Designer must have intervened here, then that's all you can say about it, no further investigation is necessary or possible, and let's go on to the next topic. This is not the way that science is done.

But this IDC approach raises more questions that IDC proponents have not been able to instruct us how to answer - at least not without invoking supernatural Creators. For example, what does this example (and others) of "irreducible complexity" tell us about the Designer of the system? Could there be more than one Designer? How would we test that proposition? Could we find the answers to these questions by scientific means, or do we have to depend on theology from this point onward? In *Pandas*, students are taught that these answers must be theological. The answer, as *Pandas* suggests, must be a Divine Creator; but if they take the approach that the Designer cannot be known by scientific means, then it is not science.

2. "Specified complexity" is the favored argument of IDC proponent William Dembski, a fellow of the DI who has a degree in mathematics but evidently in no branch of science, particularly not biology or earth science. His idea (e.g., Dembski, 1998) is that if it is sufficiently unlikely that the components of a natural phenomenon could have been assembled by chance or other natural processes, then we must conclude that it was intelligently designed. He has published his ideas in popular books and speeches, but has never subjected his full view of

"specified complexity" to peer review. His mistake is that he misapprehends how organisms evolve, and so his models of evolution are inappropriate and wrong.

Dembski proposes to erect what he considers a generous threshold of improbability. He proposes that if the probability of a combination of evolutionary events is less than 1 in 10^{150} , we should consider the intervention of an Intelligent Designer. But Dembski treats evolutionary events as if they were completely independent of each other, when they are not. Old-time creationist critics of evolution used to liken the probability of natural selection forming a complex organism to the probability that a tornado passing through a junkyard would assemble a Boeing 707. Fair enough, if that were how evolution worked, but it isn't.

Every slight genetic and phenotypic modification to an organism can be preserved by natural selection and other mechanisms. Once there, it is kept in the genetic system of the population. It does not have to be reinvented with each generation, or as each subsequent beneficial mutation appears. Moreover, rapid change is likely in populations, because if one individual is prone to a mutation in a given direction, others in the population will also be so prone, inasmuch as they share so much similar genetic material. And natural selection and other evolutionary processes can act on this feature in many individuals as easily as in one.

Dembski's fundamental error is simply analogized. He writes as if evolution were a never-ending game of dice, in which each roll had no effect upon the next in terms of the probability of successive outcomes. The probability of complex features assembling, in Dembski's world, is equal to the probability of A *times* the probability of B *times* the probability of C ... and this leads us quickly to nearly infinite improbability. But in fact, once event A has occurred in evolution, it has happened, and so the probability of B occurring in a subsequent generation (and therefore evolving the condition AB), is simply the probability of B, and not a product of the individual probabilities of A *times* B. And so on. Evolution is a bit more like a game of Monopoly. It is a cumulative process. Yes, there is chance involved, when you roll the dice. But there is also the constraint of probability, and the legacy of history. If you already have \$1500 banked, you do not start again at \$0 every time you roll the dice. If you are on Baltic Avenue, no combination of two dice could get you as far as Ventnor Avenue; but you have lots of other possibilities, and you can get there eventually. You do not start at "GO" each time the dice is thrown. So history, the accumulation of genetic and structural change, plays an important part in the game. And, though this analogy is simplistic, it shows that Dembski's formulation of "specified complexity" in no way reflects biological understanding.

Mathematical models do not prescribe reality. They can describe reality, if their initial assumptions are sound, because equations are nothing more than tautologies; they introduce no new data. Dembski's equations are based on nonsensical assumptions. Students who would be taught these notions would have to be disabused of them before they could learn science properly.

The fossil record falsifies the notion of "specified complexity" repeatedly by showing that complex structures and their functions DO evolve, step by step, not all at once, and therefore that the probability of their complete assembly cannot be simulated by a naïve model of a combination of the probabilities of their individual characteristics appearing all at once. Each step along the way is viable; the organisms that reach these steps are viable. The example given above of the evolution of feathers and their use in an airfoil is apposite; see Padian and Chiappe (1998a, b), Padian (2001), and Padian et al. (2001) for documentation of this evolutionary sequence, and Padian & Angielczyk (1995, in press) for other examples from the fossil record.

For these and other reasons, the two supposedly empirical propositions of IDC are falsified as general propositions, demonstrated to have no basis in science, and shown to be deficient as pedagogical tools.

F. IDC and the validity of the fossil record

Proponents of IDC are generally coy in their public statements about the fossil record. They do not say directly that it is a sham, as many old-time religious anti-evolutionists did, but they very directly imply it in works such as *Of Pandas and People* (Davis and Kenyon, 1993). Instead, their approach is to try to discredit what is understood of the fossil record, so that by weakening this picture the “alternative” of IDC may be introduced. Retired law professor Phillip Johnson, a founder of the Center for the Renewal of Science and Culture, the IDC arm of the Discovery Institute, and principal author of the DI's “Wedge Strategy” (other experts will address this aspect), spends a great deal of time in his book *Darwin On Trial* (2nd ed., 1993) talking about paleontology. *Darwin on Trial* has been widely quoted and disseminated by proponents of IDC, and at one point Alabama Governor Fob James distributed 40,000 copies of it to schoolteachers across his state. But Johnson has no training in science in general, let alone paleontology, and much of what he writes in his book is cribbed from anti-evolutionist Michael Denton's (1986) *Evolution: A Theory in Crisis*. Denton, in his turn, also had no expertise in paleontology or evolution, and his book is full of mistakes and illogic.

Johnson's and Denton's errors, on which the viewpoint of IDC is largely based, are legion. Take first the history and philosophy of paleontology and evolution. Johnson is wrong that Cuvier believed that episodes of extinction were followed by periods of creation (45). He completely misinterprets Darwin's view of transitional forms and the incompleteness of the fossil record (46). He does not appreciate that Darwin was talking about the origin of species, not about the evolution of major new adaptive forms (47). The validity of Darwin's theory did not depend on finding “transitional forms” in the fossil record (Bowler, 1984). Johnson does not understand that scientists search for transitional features, not transitional forms; direct ancestors are not required to substantiate evolutionary theory (Padian and Angielczyk, 1999, in press). The fossil record does not at all look like it did in 1859 (50), given that paleontologists have described a quarter of a million more species since then, and contributed numerous sophisticated mathematical analyses of the completeness of the fossil record and the pace of evolutionary change (Sepkoski, 2002). Johnson completely garbles the scientific literature on the concepts of punctuated equilibria, the fossil records of whales and bats, and the “Cambrian Explosion.” He concludes (62, mocking Darwin's closing sentence of the *Origin of Species*), “What makes our scientists so absolutely certain that everything really *did* evolve from simple beginnings?” If he had any real knowledge of the Precambrian fossil record, he would not ask such a question (Valentine, 2004).

Johnson's chapter 6, on the vertebrate fossil record, is egregiously wrong. He says that success in paleontology depends on finding ancestors, which is incorrect (we do not “look for ancestors”), and like most anti-evolutionists he overlooks the difference between lineal and collateral ancestors, which scientists do not. This is evident in the quote Johnson provides (76) from Barbara Stahl's 1975 (and greatly outdated) textbook, “none of the known fishes is thought to be directly ancestral to the earliest land vertebrates.” We are not looking for direct ancestors. What Johnson misapprehends is that the groups regarded as closest to land vertebrates had many of the characteristics that we also see in the first land vertebrates – which more distantly related groups do not. These features include stronger limb girdles, fins reinforced by thick, discrete limb bones, reduced fin rays, internal nostrils, the loss of dorsal and anal fins, and so on (Benton, 2004). We do not need to find direct ancestors; we look instead for fossil forms that have combinations of characters intermediate between some groups and others. Johnson invokes the coelacanth, a living representative of which was discovered alive in 1938, saying that although they are presumed to be close relatives of tetrapods, they have no obvious

tetrapod features. Of course not: coelacanth fossils were last found in terrestrially deposited sediments in the Cretaceous Period, over 65 million years ago. Since then, their surviving members have found success in deep offshore waters, where no land adaptations are needed. But they do have some features, such as robust limb skeletons, some internal cranial features, and a pattern of moving their limbs that is identical to how tetrapods walk, that separate them from other fishlike forms and ally them to tetrapods. Johnson further misrepresents a transition from “amphibian to reptile,” as if a frog evolved into a lizard, and then wonders why there is no explanation of the evolution from an animal that goes through metamorphosis to one who lays a hard-shelled egg. The reason is that frogs are unusual in their life cycle, and what we conceive of as “modern” amphibians, notably frogs, were nothing like the animals that gave rise to reptiles; in fact, such forms can’t even be called true amphibians. Johnson makes similar errors in considering “transitions” from reptile to bird and from reptile to mammal (both ontologically false: birds are merely a subgroup of reptiles, and mammals did not evolve from reptiles, but from a separate branch of the amniote tetrapods). Johnson did not bother to consult authorities in this field that he never studied, because he knew what he wanted to do in writing his book: to cast aspersion on the scientific understanding of evolution, and to lead his audience instead into thinking that these forms were specially created.

Another product of the DI used to discredit evolutionary biology and promote IDC is Jonathan Wells’s book *Icons of Evolution: Science or Myth?: Why much of what we teach about evolution is wrong* (2000). Wells is not an expert on evolution. Wells has never published a peer-reviewed article on paleontology or any related evolutionary subject. He received a PhD in molecular biology from Berkeley, but his research had nothing to do with evolution, and he produced no primary research beyond the experiments carried out in his professor’s lab during his graduate career. In fact, Wells took an advanced degree in biology because his spiritual master, Sun Myung Moon, leader of the Unification Church (the so-called “Moonies”), instructed him to do so in order that he might “destroy Darwinism from the inside.” Wells frankly admits all this on the Unification Church website, yet he expects readers to believe that his discussions of evolution will be knowledgeable and dispassionate (see Padian and Gishlick, 2002).

Wells has no training in paleontology, yet he feels no compunctions about representing his expertise in the field to readers. Like Johnson, he cannot distinguish between lineal and collateral ancestors. He is utterly wrong about the sequence of appearance of “four-legged” and “two-legged” reptiles in the fossil record (117). He does not understand cladistics, the theory of systematics by which biologists determine the relationships of organisms (119) (see <http://paup.csit.fsu.edu/>). He does not know that more generalized relatives of *Archaeopteryx* and other birds lived millions of years earlier (120) (Padian and Chiappe, 1998a, b). Systematists understand that because birds evolved from a group of dinosaurs, they are logically included within dinosaurs (just as if you were born in Italy but later moved to America, you would still be recognized as an Italian, even with new American clothes). Wells sees this as an irresolvable conflict. He is out of step, not just with paleontology, but with all scientists who classify all kinds of organisms, from bacteria to whales.

A further example is DI Fellow Stephen Meyer’s published views (e.g., in Dembski and Ruse, 2004) on the so-called “Cambrian Explosion.” Meyer is a professor of philosophy at a small religious college. He has never published a peer-reviewed paper in paleontology, to my knowledge. Meyer and other IDC proponents claim that many distinct lineages of invertebrate animal body plans (the traditional Linnean “phyla”) appeared suddenly in complex form during a short interval of the Cambrian Period, indicating to them that supernatural

intervention must have been involved. Meyer describes the interval in question as five million years, but the emergence of metazoans (complex multicellular animals) can be traced back nearly 70 million years earlier, when embryos of basal metazoans are now known. The “Cambrian Explosion” has been known for decades to be mainly a problem of fossil preservation, although it is acknowledged that a lot of evolution took place in a short time (which is not unique in evolutionary history). No supernatural processes appear to be required to explain this evolution. Bilaterian trace fossils and smaller shelled invertebrates are found tens of millions of years before the so-called Cambrian Explosion, so these body plans could not have evolved instantaneously, yet Meyer omits all this evidence (Valentine, 2004).

G. *Of Pandas and Paleontology*

Finally, I address the treatment of paleontology and comparative anatomy in *Of Pandas and People* (Davis and Kenyon, 2nd ed., 1993). The purpose of this book is to mislead students about what is known in science, and to instruct them that given the purported failure of science, one should turn to an Intelligent Creator to explain the diversity of life and its structures.

In “How Living Things Change” (10-11), the authors state that “the change produced by breeders is horizontal change, the flowering and elaboration of a single branch on that tree. What is needed, however, is vertical change leading up the evolutionary tree and creating a new branch. ... **microevolution**. What is needed is the origin of new types, or **macroevolution**.” This is a fundamental misunderstanding of evolution and the basic genetics behind it. There is no such thing as horizontal change. Lineages are lineages, and that is that. When families have children, they are not producing “horizontal change.” They are perpetuating their lineage. New “types,” by which these authors mean new kinds of body plans or adaptations, do not suddenly appear, and no scientific evidence supports this notion. The origin of new major adaptive types and major groups of organisms begins with a single speciation event, a very few minor structural changes. These changes accumulate, earlier species in these lineages become extinct, and eventually the new group looks substantially different from the one from which it evolved. Darwin (1859) recognized that the reason we have such apparent disparity among living groups of organisms is that selective extinction has done its work, removing older species with more transitional features. This is plainly evident in the example of the early dinosaurs with feathers, noted above.

In “Intelligent Design: package deal” the authors state (12-13) that the giraffe’s long neck and long legs form an “adaptational package” in which each part is suited to the others. They state that “it is difficult to explain how a random process could offer to natural selection an integrated package of adaptations, even over time.” It is difficult to know how the authors know this, but they could simply look at okapis and llamas, shorter-limbed and shorter-necked relatives of the giraffe, to see animals with features intermediate between those of the giraffe and more conventional hoofed animals such as antelope. This should not be characterized as a “random process,” either. Natural selection is the opposite of random, just as selective college admission is the opposite of open enrollment.

The authors completely misrepresent the fossil record (21-26). They ignore the evidence that the “Cambrian Explosion” was not sudden (see above). Their Figure 3-2 (95) shows that many major groups (animal “phyla”) did not appear at the Cambrian boundary (their graph unfortunately has no labels or scale), but they do not extend the dotted lines that they draw to the base of the Cambrian to the records of metazoan fossils in the Precambrian, which seems disingenuous. If scientists think that some of these forms were present before the P/C boundary, why not show those inferences as well?

About "Gaps in the Fossil Record," they say, "the various taxa are not connected to one another. There is no gradual series of forms leading from fish to amphibians, or from reptiles to birds. Instead, fossil types are fully formed and functional when they first appear in the fossil record." They are wrong on all counts. First, as noted above, scientists do not search for intermediate fossil forms, but for organisms that may show some intermediate features, even though in other ways they may be unique. This recalls the difference between direct (lineal) and collateral ancestors noted above. Second, we have many such animals with transitional features germane to the examples they list. Third, fossil types are not "fully formed" when they first appear. The first known bird, *Archaeopteryx*, has very few characteristics apart from a feathered wing that would allow us to recognize it as closer to living birds than to other small carnivorous dinosaurs, and many of its dinosaurian relatives already have well-developed feathers (but not a fully developed airworthy wing). We have many Cretaceous birds after *Archaeopteryx* that show gradually increasing similarity to the living groups of birds, such as *Eoalulavis*, *Confuciusornis*, *Sinornis*, *Rahonavis*, *Hesperornis*, and *Ichthyornis* (e.g., Padian and Chiappe 1998a, b; Chiappe and Witmer 2002). They show successive modifications for the improvement of flight ability and the diversification into aerial functions. The *Pandas* authors do not know, or do not wish their readers to know, about this evidence. They tell their readers to conclude instead that "an intelligent cause made fully-formed and functional creatures, which later left their traces in the rocks." This view is actually pre-Enlightenment; scientists of the 1600s, including Steno and da Vinci, knew better about the origins of fossils and rocks.

The misrepresentation of the vertebrate fossil record by the *Pandas* authors (100-113) is appalling. On the origin of mammals (101), the hypothesis that mammals had several independent origins has not been seriously considered for half a century, although as in many groups, some mammalian features may have evolved independently in related groups (Rich et al., 2005). Their Figure 4-7 (103) has a graph-paper scale that falsely implies geologic time; the categories of mammals they list, such as "Mesozoic mammals," "advanced carnivores," and "advanced ungulates," are vague or artificial, and the assigned time ranges are misleading or wrong. We do not find rabbits, sloths and armadillos in the Middle and Late Cretaceous (e.g., Asher et al., 2005), and by omitting many extinct mammal groups the authors give the impression that there are no other groups from which living mammals could evolve.

The authors' account of the origin of whales (101-102) is outdated and incorrect; a great deal of new evidence, many new fossil taxa, and advances in paleoecological understanding have been brought to the fore in the past two decades (even before this book was published). This brings up one of the dangers of teaching IDC as if it were scientific; if you rest your case on a lack of evidence, and then evidence emerges, not only does your case against the science collapse, but your case for an alternative becomes weaker. We have a very strong fossil sequence of the early evolution of whales, which documents changes in the teeth, the telescoping of the skull, the adjustment of the ear, the modifications of the vertebral column, the reduction of the limbs and their separation from the pelvis (this was not for copulatory purposes, as the *Pandas* text pretends), and the changes involved in producing flippers from forelimbs. Paleoecological studies also show that early whales progressively moved from riverine to estuarine to near-shore to offshore environments (Padian and Angielczyk 1995, in press; Thewissen 1998). The authors are correct that the extinct mesonychians have been invoked as distant relatives of whales (Figure 4-5), but no one has suggested that *Mesonyx* is the direct ancestor of whales.

As a vertebrate morphologist, I must also note some extraordinary statements that the authors make about zoology. They note (29), "The marsupial wolf is strikingly similar to the placental wolf in most features, yet it is like the kangaroo in one significant feature [they mean in having a pouch]. Upon which similarity do we build our classification scheme?" Zoologists

have known since the early 19th-Century days of Cuvier and Owen (who were not in any sense Darwinians) that marsupials differ from placental mammals by far more than the pouch, including dental formulae, skull bone configurations, soft tissue morphology, and physiological features, to which we may now add a tremendous amount of biochemical evidence. It is obvious even from their own drawing (Fig. 5-2, p. 117) that the marsupial "wolf" has three more cheek teeth than the dog and wolf, that these teeth are morphologically quite different, that their petrosal bullae (ear regions) are completely different, and that the marsupial's zygomatic arch extends much further posteriorly. Many more contrasts would be evident if the drawings were accurate, if skull bones were indicated, and if ventral and dorsal views were provided. A student in a beginning zoology course would fail it if he or she could not evaluate these obvious and telling differences. The *Pandas* authors are trying to suggest that biological classification is simply arbitrary, and so keep their readers ignorant of how organisms are classified. They do the same with the conundrum (118-121) of the "giant panda" and the "red panda," which are not closely related; scientists have known for decades that the first is a bear and the second is a type of raccoon, and the only similarity is the Chinese common name. There is no reasonable controversy about this.

In a similar vein, the *Pandas* authors state (23) that "*Archaeopteryx* has only one birdlike feature, much like the duck-billed platypus [i.e., a bill]." *Archaeopteryx* does not have a bill at all. It has a narrow, pointed, toothed, bony snout, like its dinosaurian relatives. The platypus has a broad, leathery, prehensile snout that lacks the sharp, needle-like teeth found in *Archaeopteryx*, and no one would ever mistake the two structures for each other. *Archaeopteryx* has many features that birds have that the platypus does not, and it is amazing that the *Pandas* authors did not research this before writing their second edition.

The *Pandas* treatment of what they call "Amphibians" (104) is erroneous in so many respects that it is difficult to know where to begin. The first amphibians were not "labyrinthodonts," which is a type of tooth, not a type of animal. Crossopterygians are not "early fish"; they are not fishes at all, but a group that includes all tetrapods plus some non-terrestrial relatives of tetrapods. *Ichthyostega* is not the oldest known amphibian; it is not an amphibian at all, but an early crossopterygian. Crossopterygians did not "evolve into amphibians"; amphibians evolved from among the first tetrapod groups, but so did many other groups, including reptiles and the lineage that eventually included mammals (synapsids) (Laurin, 1998). The alleged "ichthyostegid forelimb" pictured in Figure 4-9 cannot be that of *Ichthyostega* or anything close to it, as even the picture of *Ichthyostega* in their Figure 4-8 shows. *Ichthyostega* had a forelimb with 7 digits and probably did not walk on land; the animal shown in Figure 4-9 has an elbow bent at right angles, two rows of discrete wrist bones, and only five digits. This is not merely wrong; it is misleading. If more than two drawings were included in that figure, readers would be able to see how these two showed features intermediate between more primitive features of early vertebrates and the more derived features of land animals. In the gradual course of the emergence of vertebrates onto land, the digital formula, for example, was reduced from 8 to 7 to 6 to 5 digits as these animals emerged progressively from the water. The shoulder separated from the head; neck vertebrae evolved that allowed up-and-down motion of the head (the axis) and then side-to-side motion (the atlas); the limbs became more robust; the vertebrae evolved interlocking spines that prevented the guts from being crushed; the dorsal and anal fins were lost; the pelvic girdle was attached to the backbone. These features did not occur all at once, but sequentially in progressively more terrestrial vertebrates. A correctly drawn picture of *Ichthyostega* or *Acanthostega* would also show some obvious intermediate features between the two drawings on that page.

The section on *Archaeopteryx*, the first known bird (104-106), is equally incorrect and misleading. The authors attempt to dichotomize this Jurassic fossil and living birds, noting that

the latter have an “adaptive package” that includes “necessities” such as a sternum, wishbone, “the anchoring of major wing feathers to the ulna by ligaments, and several others [sic].” *Archaeopteryx* does not have a bony sternum as far as we know (e.g., Wellnhofer and Tischlinger, 2004), but cartilaginous structures are almost never preserved in the fossil record, and much of the sternum in living birds can be cartilaginous, yet they can still fly (so can bats, though they have nothing comparable to a bird sternum). *Archaeopteryx* does, contrary to this text, have a very robust wishbone; it is boomerang-shaped and very solid, as paleontologists know. The *Pandas* authors list nine characteristics that ally *Archaeopteryx* with “reptiles” instead of birds; six of these are wrong. Of the others, a three-clawed hand is present only in the theropod dinosaurs from which birds evolved, not in other reptiles; a “long spinal tail [sic]” is a nonsensical statement, but the tail in *Archaeopteryx* is like the tail in its theropod relatives, reduced to about 23 vertebrae with a transition point to greatly reduced haemal arches quite proximal to its base; so these two features *actually link birds to carnivorous dinosaurs*, which is the conclusion of paleontologists (Padian and Chiappe, 1998b). Finally, “ribs without uncinatate processes” could as well apply to humans and dogs (not all birds have them either). The authors say that John Ostrom, the premier authority on *Archaeopteryx* of the last thirty years, said that *Archaeopteryx* “was incapable of flight and used its wings to chase down insects instead.” This is false, as I can attest because Ostrom was one of my dissertation advisors: he thought it could fly, though not very well, and he genially retracted his “insect net” hypothesis, as good scientists are supposed to do, when other scientists presented good lines of evidence to show that it was not plausible. This would be a good example of how science is and should be done, but it is doubtful that the *Pandas* authors were interested in showing this. Instead, they quote the alleged authority of “Professor David Wilcox,” who is not a recognized expert on *Archaeopteryx* or avian paleontology, that there is no evidence for the evolution of flight features in birds. He is quite wrong, as decades of research by experts have pointed out (for reviews, see Padian and Chiappe 1998a, 1998b; Padian 2001), and tellingly, his remarks are not published in the scientific literature, but in a book called *The Creation: Spoken in Eternity, Unfolded in Time*. This is the kind of authority that IDC proponents want students to heed.

H. IDC Misuse of the Theory of Punctuated Equilibria

Many anti-evolutionists, from Wendell Bird to Phillip Johnson, and including the authors of *Pandas*, have tried to use the theory of “punctuated equilibria” to imply that evolution or major groups of plants and animals is too discontinuous to be explained by natural means, and that therefore a Creator’s influence should be invoked. This is a complete misrepresentation of Eldredge and Gould’s (1972) theory. They were not speaking of the origin of major adaptations and new body plans (nor was Darwin in the *Origin of Species*). They were talking about the origin of what we recognize in the fossil record as species. They noted that within populations of fossil organisms, when they are well enough preserved, change from the first to last members of a lineage is usually not gradual; in fact little directional change at all is generally observed. Then, within a relatively short period of time, we see a shift to a slightly different new morphology, which we recognize as a new species. This recognition of differences among fossil species accords with studies of differences between most closely related species of living forms (e.g., Jackson and Cheetham [1990] comparing living and fossil bryozoans). The “equilibria” reflect the observation of relative stasis for most of the duration of the species; the “punctuation” represents the relatively short time during which meaningful directional change to a new form takes place. Eldredge and Gould did not say that this is *always* the case in fossil lineages; they predicted that when all cases were re-assessed in light of their hypothesis, the vast majority would turn out to show this pattern.

Eldredge and Gould couched their theory in accordance with models of speciation that were accepted in the 1960s by population biologists. Ernst Mayr, the dean of evolutionary biologists for many decades, had proposed that most new speciation events probably took place in small populations at the periphery of a species's geographic range, and probably happened relatively rapidly. The effect of this would be to see a species that appeared rather uniform in its morphology through time, but could be replaced quickly by a new daughter form that had speciated at the edge of the species's range.

The foregoing demonstrates that "punctuated equilibria," like Darwin's original work, was not devised to explain the "sudden appearance" (in creationist Wendell Bird's [1987] parlance) of *major new body plans*, but of the ordinary origin of new species. Anti-evolutionists, including IDC proponents, have misunderstood this literature and have used the concept inappropriately and misleadingly in popular publications for 30 years. Their accounts of these and other aspects of paleontological and evolutionary theory are not accurate or authoritative; they are false.

I. IDC and the scientific community

Two hallmarks of modern science are that it is testable, and it has been vetted by peer review. "Testable" means that when an idea is proposed, some line (preferably several independent lines) of empirical evidence can be adduced to the proposal, and that this evidence could help to determine whether the proposal is supported and plausible. Often, contrary lines of empirical evidence can make such a proposal so unlikely that we say that it is thereby falsified. But there is no way that IDC proponents will accept that their Intelligent Designer cannot exist; this premise is their central *raison d'être* and cannot be negated, or they lose their whole argument.

As noted above, two main pillars of the argument "for" IDC are "irreducible complexity" and "specified complexity." Let us say that specific examples of both were proposed by IDC advocates, and that these specific examples were shown to be spurious ("falsified") by other empirical evidence. Science often addresses propositions in *deductive* or *inductive* terms (or both), depending on the proposition and how it can be tested. On simple *deductive* grounds, let us say that a highly complex structure is not capable of being assembled piece by piece, and therefore must be assembled by a creative force that defies natural patterns and processes. Now, let us say that such a given case was falsified by finding a partially assembled stage that worked quite well. One could argue that this means there is no Designer, but we do not teach this in science classes, because scientists do not consider the Supernatural part of their discipline (IDC proponents urge otherwise).

Now, taking an *inductive*, not deductive approach, an IDC proponent might claim that irreducible complexity was rejected in this case, but not as a general proposition. We would need to examine all possible cases before we could say that there was no evidence for a Designer. However, *irreducible complexity has never been established in the first place as a scientific, philosophical, or theological proposition*. And so it cannot be tested as science. The IDC argument here is much like the case where a man who believes he has witnessed a faith healing is shown that the "healer" in question did not really remove a tumor, but simply squashed some previously sequestered chicken liver. The believer responds that this may have been how the other fellow did it, but that doesn't mean that the "healer" isn't genuine.

IDC proponents depend on gulling the public into believing that their precepts are already acceptable scientifically, so that even if all proposed cases are falsified, the precepts refuse to die. This is not science, but religion. It is not testable. Nothing would make IDC proponents reject their propositions; they are matters of faith, not of science. IDC proponents

reject the standard methods of science. Our knowledge of the fossil record, in contrast, is inductive: we derive general inferences based on countless examples, which present us with repeatedly tested and confirmed patterns from which the history of life is reconstructed. These patterns, and the processes inferred to produce them, are in turn based on conventional scientific methods, and the progression of life through time shows no evidence of intelligent design, no examples where we must invoke "irreducible complexity" or "specified complexity."

A second hallmark of modern science is peer review. Although IDC has been highly active in sociopolitical arenas since the early 1990s, and although its proponents wish to claim equal consideration in science education programs, the fact is that not a single peer-reviewed paper testing a proposition of IDC has ever been published. The IDC crowd is not interested in doing actual science (Pennock 1999; Forrest and Gross 2004; Shanks 2004; Scott 2004; Taner and Edis 2004). They have no laboratories, no research grants, no field studies, no museums or museum studies, no experiments that test their beliefs. They have no results to submit to the scientific community for peer review. Peer review means that a manuscript is submitted to a journal, whose editor sends it to experts in the field to determine if the science is methodologically acceptable or has flaws that need correcting, in which case the authors may attempt to address them. Non-reviewed publications are not seriously considered by the scientific community. Peer review does not ensure that a published article is correct; it attempts to exact a measure of quality control on which the journal and its editors base their reputations. Many scientific findings are modified or overturned by later discoveries, and this is part of the natural process of science. But IDC proponents reject this approach, which is the heart of science.

Our understanding of the fossil record has been modified through time, but it provides no evidence for the precepts of IDC and no need to invoke a supernatural Creator to explain its patterns. The fossil record is not chaotic in the sequence of appearance of various groups of animals and plants; we do not find horses in the Cambrian Period, jawless animals appear before jawed ones, and the first land animals somewhat later; and so on. All these patterns are well known in the peer-reviewed scientific literature, but IDC is nowhere represented in this literature. The IDC proponents are not doing science; they are aping it. They seem to count on the idea that the trappings of science will convince a scientifically naïve public of their case. They have no interest in the exercise of demonstrating the merits of their proposition to the scientific community. If they did, they would produce testable propositions and submit their ideas to peer review.

In conclusion, the order of appearance of the major groups of plants and animals accords with the expectations and patterns of the evidence and theory of contemporary evolutionary biology, and not at all with the notion of intermittent intervention by an Intelligent Designer who needs to create new biological solutions to the problem of life *ex nihilo*.

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A handwritten signature in black ink, appearing to be 'K. Padian', written in a cursive style.

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