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# CREATIVE PALEONTOLOGY

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Paleontology requires creativity. Why? Because it is not an easy science. It is a way to understand the history of life through repeated, reliable observations as well as hypothesis development and testing in the face of limited and often confusing data. Other paleontologists must be able, nevertheless, to repeat the observations and to test the hypotheses. This process is, of course, the core of science itself, not just paleontology. The way we do this, however, is the creative part of paleontology and science in general. In my last editorial here (Lipps, 2000), I suggested some ways that we might encourage creativity in paleontology. In this present essay, I'd like to discuss where creativity enters into our daily activities and how applying the methods of science can produce creativity, if done right. The best paleontologists are the most creative ones. How can we be creative? How can we teach creativity?

Creative science is a process without rules on how to do it. Creativity is not always easy to generate in science because the subjects we study and the procedures we use are quite complicated, but it is essential to breakthrough discoveries and outstanding new hypotheses. It requires certain thought processes, work habits, and skills. In science, we are not free to pursue just any idea or thought—we are more constrained (not only in our abilities) than Picasso or Mozart were—but instead, we must create from within the framework of existing data and hypotheses. That takes skill and ingenuity.The creative process in science requires certain skills—critical thinking and evidential reasoning (Lett 1990; Lipps 1999a, 1999b; Wade and Travis 1990). From these skills, creativity can flow. A good deal of work in science goes on without significant display of these skills, but if all paleontological data and supposed hypotheses were subjected to harsh and thorough scrutiny by critical thinking and evidential reasoning, we'd be much farther along.Paleontologists, like many other historical scientists, are limited in a sense by a paucity of data, but, as a result, they have more freedom to generate hypotheses. Not crazy ideas developed in the face of few data, but clever use of those data, meager or not, to develop testable hypotheses. While this is not easy, it is the stuff of paleontological creativity and progress. In order to do this well, paleontologists must be excited and innovative.

So how do paleontologists work and where does creativity enter effectively? Paleontologists, like all scientists, engage in three fundamental activities. They gather data, develop hypotheses, and test hypotheses, not necessarily in that order. Rarely do they get further, to the theory stage. Within these activities, individual scientists may work differently and. They are free to be creative and innovative in their own way. But there are certain ways of doing this work that promote creativity more than others (Platt 1964).

**Data gathering** is the accumulation of facts, experimental, observational, or mathematical. In paleontology, this activity most often involves fieldwork and specimen study. We've been doing it for hundreds of years—sometimes creatively, mostly not. Fossils can only be found,collected, sorted, curated, studied, and described in so many ways, and we've largely ritualized those. Creativity has suffered. This kind of descriptive science was, for many decades in the 19th century, exactly what science was all about. Different branches of science came out of that phase at different times, but paleontology, overwhelmed by the task and beseeched by geologists to provide stratigraphic conclusions, continued to be largely descriptive

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until the mid-20th century. Paleontology still is largely descriptive, and that's not bad. It is the nature of the field. It works and it's fundamental to our progress. We can't quit. But it's not very creative. It could be, but only with extraordinary thought. Creativity is possible, mostly in figuring out new techniques of analysis in the field and the laboratory, and keeping an open mind to new approaches. Do not reject these out of hand—think first. I have no particular ways to promote creativity in our data collection, other than to observe and record carefully, to think hard, and to read widely on how others outside paleontology do it. Intellectual cross-fertilization helps enormously.

**Hypothesis development** can be very creative. It is tricky, because all hypotheses are ideas at some stage, and an idea without structuring data is not an hypothesis. This is where many non-scientists and not a few practicing scientists go astray. A scientific hypothesis differs significantly from a theory in the common non-scientific sense. "Theory" in that sense means an **ad hoc** idea, which may rest on little more than some correlation, favorite story, hearsay, or wish. It does not have to be based on critical thinking or evidential reasoning. This is not scientific creativity. This common usage of "theory" should not be confused with the scientific use of "theory" or "hypothesis". Scientists should also use care in constructing hypotheses that are based on the necessary data and consistent with known scientific facts. For example, a paleontologist might well think that dinosaurs became extinct because they were poisoned by aliens from outer space, but that remains an **ad hoc** idea unworthy of further consideration until data exist that might reasonably be interpreted to support or suggest it. We don't need more unsupported ideas; we need testable hypotheses. This requires creativity!

Hypothesis development should be a careful process guided by critical thinking and evidential reasoning. A hypothesis requires careful inspection and analysis of the data to be testable and to have predictive power. It must be consistent with all known data, and it must fit logically within other accepted hypotheses in science. A test must attempt to disprove the hypothesis since proof in science cannot be attained. The more critical tests that a hypothesis passes, the more confidence we can have in it. Creativity looms large in this process.

**A single idea, model or hypothesis** is commonly developed by a scientist to explain a set of observations. Our paleontological journals are full of these; many excellent, some bad. A large number of paleontologists stop with the development of just one hypothesis that accounts for their observations. However, the single-hypothesis method is fraught with many pitfalls, and it limits creativity. Data that do not fit the hypothesis are easy to ignore because they cannot be used in any other place. Thus, the data collected tend to support the hypothesis, yet the best-supported hypothesis can still fail on a single critical observation. Creativity is stifled. Furthermore, a scientist with a single hypothesis has his ego at stake. He is forced to defend his idea because it is the only one that he possesses. He thus resists counter hypotheses or even rational discussion by other scientists. Because scientists have egos—just like other people—this allegiance to a single hypothesis results in a loss of objectivity. Sometimes bitterness may ensue and controversy abound when others try to disprove the hypothesis. Creativity is deadened. Our own egos and desires to be right, to promote ourselves, and to defend our ideas generate a flawed creativity that is usually biased, twisted and not long-lasting. Such creativity is not what we seek. Within the paleontological community at large, however, creativity can be advanced by a single hypothesis, correct or incorrect, because others take great delight in the attempts to disprove it, and, as Darwin noted in 1874, science advances.

**The Method of Multiple Working Hypotheses** was laid out more than a hundred years ago by Chicago geologist T.C. Chamberlain (1897). Sixty-seven years later, John Platt (1964) seized on the idea and pressed the method to a new audience as a highly productive and very efficient way for scientists in general to work. While this method and both Chamberlain's and Platt's papers should be well known to paleontologists and scientists in general, I'd like to suggest that, done properly and consistently, this method also provides a most effective way to be creative within the confines of science. In this method, a scientist develops multiple alternative hypotheses that might account for the observations, and then goes on to test each one. In this way, one's ego is attached not to a single hypothesis, but to the development and testing of an array of them (Platt 1964). The scientist has an easier time using all the data, for many hypotheses are available to apply them to. Furthermore, single tests can be devised for each hypothesis, and those that fail can be eliminated rapidly, thus increasing the efficiency of scientific progress. The entire process becomes a puzzle to be solved in the most creative manner.

Developing multiple working hypotheses is a powerful way to initiate and continue a creative process. For those hypotheses that survive all applied tests, they can be arranged in some order of more probable to less probable based on the degree of support generated for each from the data, their consistency with other hypotheses, and their predictive value. This arrangement might then suggest other research plans for future workers who may have additional data or newer techniques. In applied situations, where decisions must be made on incomplete information (e.g., health or environmental issues), a scientist left with two or three hypotheses can still make an informed decision based on which one is best supported by the available evidence. Science is thus more efficient when the method of "multiple working hypotheses" is fully utilized. It is also far more creative.

Creativity comes hard to a scientist who might, for example, spend his life describing snails in outcrops and know only that each outcrop has some number of snails without understanding why. While it might be important, it is not particularly creative because no hypotheses are formulated from the observations to further guide the research. A second scientist might have a single favorite hypothesis, say that the snails occur in those outcrops because of better preservation. This scientist will work hard and long to find ways to defend his assertion, which will likely generate some creative solutions, for he has no alternatives except trying to prove his idea. While this can be creative, it is a limited creativity based largely on the defense of the hypothesis. A third scientist, using the method of multiple working hypotheses, will acquire some data, develop a number of hypotheses to account for those observations, then design tests that have the potential to disprove (not prove) each hypothesis. Each hypothesis and each test requires ingenuity and careful thought about the relationships of many things among themselves and to other scientific knowledge. This induces critical thinking, evidential reasoning, and ultimately a high degree of creativity. A single failed test allows that hypothesis to be discarded. In this process, additional data are collected that can be brought to bear on the remaining hypotheses, as well as the development of yet additional ones. A large number of possibilities are dealt with efficiently and quickly. The third scientist moves through all proposed hypotheses, eliminating some and accumulating evidence to support those remaining. Imagination and inventiveness should be running wild with possibilities. This is the essence of creativity.

**Science is not based on faith,** as some critics have asserted. It is also not based on random or **ad hoc** creativity, but on creativity structured by the data and hypotheses of the field. If we are knowledgeable in the scientific process we accept the proclamations of other scientists outside our own field of expertise, because we know that the creative process yields multiple, testable hypotheses subject to elimination. A hypothesis, not yet disproved, may not be correct but we accept it anyway, tentatively at least, knowing that it is subject to scrutiny and correction by other scientists more expert and creative in that particular field. As a paleontologist, for instance, I tentatively accept Einstein's Theory of Relativity, not on the basis of faith, as some people would assert, but on the knowledge that it has been tested, is being tested, will continue to be tested, and so far has withstood those tests. Faith is not involved at all. I am ready to change my mind as soon as I understand from other authorities in physics that Einstein's theory has failed a definitive test. The same goes for evolution!Some hypotheses and theories may not yet have been subjected to the critical tests. This is common in paleontology, either because no other paleontologist has gotten interested in the problem, the technology required to make the test has not been developed, or the proper discoveries have not yet been made. Someday, someone will likely test these as well. In this sense, science is self-correcting and errors are eliminated—not immediately, but eventually they will be. In rapidly moving fields, like molecular biology, corrections come every day; in other less active fields, say sponge systematics, corrections may take decades if not centuries. Paleontological creativeness can be a slow process.All of this needs to be taught to our students right along with the principles of paleontology, so that creativity is in the forepart of their minds. Every time we talk to them about their research, we should also ask what multiple or alternative hypotheses they have formulated. Ask them what other evidence they can find to bring to bear on the problem. Ask if they can imagine better methods. We should prod them constantly to think critically, reason evidentially, and be creative at every step in their program. We should also remind ourselves once in a while how to build creativeness into our daily routines. Our science and our paleontological lives will be better.

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