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T. rex and Godzilla: Finding Science in Science Fiction

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Abstract

Works of fiction act as a powerful vehicle for inculcating an intuitive understanding (or misunderstanding) of scientific concepts in the audience. They can communicate information about scientific phenomena or how science is done. These entertainments can contribute to scientific literacy of the public and provide valuable outreach opportunities, but scientific accuracy is rarely even a minor consideration in developing fictional stories. Science educators can still make use of popular fiction to promote science education and outreach.

Varied approaches have focused on the physical science in classic space operas, but historical sciences can make use of public interest in fictional tales involving prehistoric creatures and settings. Dinosaurs like *T. rex* inspire awe and widespread popular appeal that can nurture an interest in fossils but also serves as a gateway to all the other sciences on which paleontology depends, and to the scientific endeavor itself. But the portrayal of dinosaurs has met with negative criticism of details that is not likely to be productive of further discussion and learning. Perhaps it is not so important that authors and film makers didn't get it right; that "correctness" of terms and reconstructions is less important than the opportunity to improve public understanding of how science works; to cultivate a habit of critical thinking and an analytical approach to interpreting the world.

Dinosaurs and other long extinct creatures can provide examples of how we know what we know; what kind of evidence is available and how it can be interpreted; how creative framing of hypotheses allows imaginative conjectures to be constrained by observations. They can open informative discussions of how scientists work in gathering data and developing and testing hypotheses. For example, how do paleontologists find fossils?

Monsters, unrealistic fantasy creatures like Godzilla, have great charismatic appeal, and can prompt discussions of the obstacles posed by physical laws to the actual existence of such phenomena, such as the effects of such large scale on mass and inertia. Alternatively, one could undertake a scientifically constrained flight of fancy that considers what properties would be needed to make such fantastic beasts possible.

Imagination and creativity can bring real science to fiction.

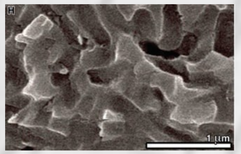
Real Science of Dinosaurs

The popularity of stories that include dinosaurs can create opportunities to introduce them into conversations at many levels, and this creates opportunities for science education. How best to take advantage of this opportunity? Rather than faulting the fictional representation of dinosaurs for inaccuracies in the depiction, it would be more productive to address the question, "How can we know this about dinosaurs?" "What is the nature of the evidence and how do we get from these facts to the interpretation of the once-living animal?" An understanding of the answers to these questions provides insight into the nature of science that is more valuable than knowledge of any particular fact.

A surprising amount of information about dinosaurs can be derived from rare, remarkable specimens and ingenuity in posing research questions. Some examples illustrate the extraordinary nature of such rare specimens and how recognition of subtle features can yield astonishing interpretations.

Example 1 – Color patterns in bird-like dinosaurs

Over the last few decades, several remarkable fossils of birds and non-avian dinosaurs have been found that preserve the remains of feathers. In some of these, it has been discovered that there are impressions of melanosomes, tiny bodies that control coloration. By studying the size, shape and density of melanosomes in modern animals and using this information to interpret the impressions of melanosomes in the plumage of a remarkably well preserved specimen of the feathered dinosaur. *Anchiornis huxleyi*, Li et al. (2010) have been able to discover the color pattern in its plumage (Fig. 3).



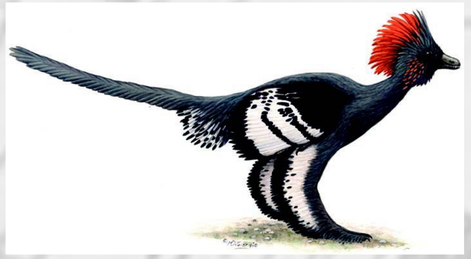


Fig. 3 Scanning Electron Micrograph of impressions of melanosomes in the plumage of A. huxleyi (above) and a reconstruction of A. huxleyi with color patterns (right). Both illustrations from Li et al. (2010).

Example 2 – Using fossil tracks to discover how dinosaurs walked

Fossil bones come from a dead animal, but trace fossils, such as tracks or trackways (series of tracks made by one animal walking) were made by a living animal and can tell you something about how that animal lived. One example of how this type of evidence can be analyzed is a recent study by Bishop et al. (2017) in which they compared the parameters measured from the trackway of an early dinosaur (Fig. 4) with similar parameters measured from the trackways of modern birds and other bipeds. Their analysis enabled them to interpret the gait of the extinct dinosaur.

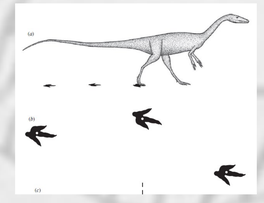


Fig. 4 Hypothetical dinosaurian trackmaker (above) and the 3-track trackway analyzed for gait. From Bishop et al. (2017)

The Problem/Opportunity

Stories, whether based in reality or wholly fictional, have a powerful educational impact. Science fiction and fantasy, especially when enhanced by sophisticated, computer-generated visual effects, is an increasingly popular genre that reaches a huge audience of children and adults. The intuitive reality of the objects and events portrayed can present a significant potential problem for science education, but can also be seen as an opportunity to introduce real science to the audience whose interest has been piqued by the stories.

Phenomena that are the objects of scientific study are important, sometimes key, elements in what may be considered broadly as science fiction. How they are rendered gives the audience a sense of familiarity with these phenomena, a sense that they know and understand them, their characteristic properties and behavior. In addition, it is not uncommon in science fiction to portray scientists and a representation of how science is done. This similarly engenders a sense of understanding how science works. This effect results in a very powerful form of informal, even subliminal education that is given broad public exposure.

The potential problem is that if the scientific phenomena or scientific process are misrepresented, the erroneous information can be implanted in the minds of the public, often accompanied by confidence in how well-informed they are. If this is the case, as it often is, the best outcome for STEM education is that the misinformation must be unlearned, sometimes with difficulty, when learning more accurate information from a reliable source, something not everyone will do. Although poor understanding of specific phenomena may never have much impact on a given person's life, a more serious consequence arising from casual miseducation is the false impression of how science works. This can leave people vulnerable to persuasion that purports to have a scientific basis, unable to distinguish between scientific knowledge and pseudoscience, and this can have serious consequences for the outcomes of social and political choices.

But popular science fiction can also provide opportunities for STEM education. Because it stirs widespread interest in subjects of scientific investigation, it can increase public awareness of these topics and stimulate conversations about them in a range of forums. It can make people more open to learning something about the real science that underlies or trumps the science fiction. But this will only happen if scientists and science educators are prepared to take advantage of such fortuitous openings. Simply denouncing inaccuracies is not a strategy that is likely to yield positive results, but an approach that reveals how science really works and enables us to discover what we really know about the topic, as well as the limitations of science, is more likely to be valuable and better received.

Turning Fantasy into Science

Another type of science fiction creates fantasy creatures not based on any real animal. Some of these creatures are dinosaur-like in some ways. Godzilla is one such creature that has become a cultural icon, nearly universally recognized and enduring for generations. Like dinosaurs, Godzilla can also be a gateway to science education. A number of strategies for this are possible. Some paleontologists and science writers have taken up the Godzilla challenge in print or online. Such exercises allow the scientist to approach the subject with a playful attitude that is seldom evident in "serious" science but is more characteristic of the way science is actually done.

Ken Carpenter (1998) wrote a paper in which he treated Godzilla as a dinosaur (Fig. 5) and discussed how it should be classified. The discussion is instructive of the approach and methods of taxonomy, a fundamental field within Biology.

In 2010, Darren Naish discussed Godzilla in his blog, Tetrapod Zoology (http://scienceblogs.com/tetrapodzoology/ , This is the url for the now-defunct version of the blog, but does archive these old articles.). Naish's (2010) discussion of "The Science of Godzilla, 2010" is wide-ranging and includes another approach to science education that considers the effects of scale on the strength of materials versus the forces they must resist in such an enormous creature (Fig. 6) (Naish, 2010).

Another possible approach that has not been explored is to take the materials and forces problem and stand it on its head. One could ask the question. How would a creature with the same size and outward characteristics as Godzilla have to be constructed to exist in our world? Would a titanium skeleton do the trick?

Fig. 5 Godzilla considered as a dinosaur. Small silhouette is a *Tyrannosaurus rex* for scale. From Carpenter (1998).

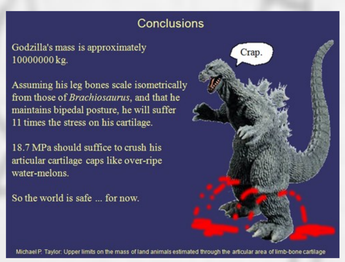


Fig. 6 The scale problem for gigantic fantasy creatures presented in an unpublished slide show by Michael P. Taylor included in a blog by Naish (2010).

Real Objects of Science Fiction: Dinosaurs

Real objects of scientific study, whether material or conceptual, are the hallmark of science fiction. Sometimes they are essential to the story through action or constraints, sometimes just the MacGuffin around which the story unfolds. Dinosaurs are very popular in this role and appear frequently in fictional stories.

Dinosaurs are inherently interesting. From their earliest discovery, they have been regarded with awe. The very name dinosaur means "terrible (in the sense of awe-inspiring) lizard." Not only are many of the dinosaurs best known to the public imposing creatures, but they conjure in the imagination a whole alien world absent humans, yet familiar as home. This makes them natural objects of science fiction stories. Even before much was known about dinosaurs, scientists and non-scientists alike were speculating on their characteristics. Early reconstructions, based on few, very incomplete specimens and comparisons with modern animals were very inaccurate in light of later, better-informed reconstructions (Fig. 1).

Accuracy within the limits of the current state of scientific knowledge has never been a requirement of works of fiction though, so, many misconceptions about dinosaurs that have become lodged in popular imagination have been incorporated in their portrayal. In addition to this, in fiction, the artist (author, director, animator, etc.) is free to apply a personal artistic vision to the representation of these real creatures. For example, the velociraptors of the Jurassic Park movies are more than twice the size of real Velociraptor (Fig. 2).

As noted above, whether the average person's idea of the characteristics of any given extinct species is accurate in terms of the current state of the science (a moving target in any case) is not likely to be important to the individual or society. More important is the portrayal of the science that accompanies the dinosaurs. Whether it comes in the form of explanations that offer a rationale for the phenomena and events or cautionary statements about the behavior and capabilities of the creatures, scientific knowledge is dispensed in a way that makes it seem to come from an oracular source incomprehensible to ordinary people. Science of this sort must be accepted uncritically or reasonably rejected as wholly fabricated; in other words, no science at all.

Fig. 1 19th century reconstruction of the dinosaur *Iguanodon* from the on the grounds of the Crystal Palace in London (above) compared to a complete skeleton of *Iguanodon* (right).

Fig. 2 Cast of a skull of *Velociraptor* (left) compared to *Velociraptor* as rendered in the recent movie Jurassic World.

A Plea for Early Inclusion of Science in the Creation of Fiction

This discussion has focused on ways to exploit popular fiction as a means of initiating experiences that further science education. But as mentioned in the introduction, such an aftermarket approach is making the best of the situation as we find it and is not really optimal. If valid science were woven into the fiction as it is being produced, ideally from the very beginning, the audience would learn sound science with the same, seemingly effortless, intuitive ease that they learn misconceptions when they are being entertained.

When it comes to dinosaurs (and a great many other things), the reality itself, without exaggeration, offers more than enough amazement for a good story. Similarly, the actual practice of science can be as or more exciting than the parody of it often presented to the public.

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