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bout Our Cover

American Toad (Bufo [Anaxyrus] americanus)
master of stealth and disguise. It relies
oloration (capable of changing to match
ackground) and warty-textured skin as
as behavior (remaining motionless when
ng and when threatened with being eaten;
g primarily nocturnal) to blend in with its
ground while it pursues prey and avoids
lators. If those strategies fail with respect to
lators, it releases poisonous subcutaneous
etions when being eaten. It uses several
ing behaviors to capture its diet of insects,
s, and a range of other invertebrates. If its
r is within 2 inches, the toad will quickly
ase its long, sticky tongue. When farther
y, it uses a "leap-sit-leap-sit" strategy.
se behaviors make toads (at least relatively)
perative photographic subjects.
e typical adult American toad is 2–4 inches
ze, the females being larger than the males.
t die within the first year of birth, but they
live up to 5–7 years in the wild. They become
ally mature in 2–3 years. When mating, the
e grabs hold of the female and they remain
ionless to avoid predators or interruption
mate-seeking males. The female will lay as
y as 8000 eggs in gelatinous strands up to
long. The eggs are countershaded (light
ve and dark below) to minimize predation.
y typically hatch within a week to 10 days
morph from tadpole to toad in 6–8 weeks
ending on the temperature).
ome additional interesting facts about
erican toads: contrary to popular belief,
y do not produce warts when handled by
nans (however, they may release poisonous
etions and should be handled with care);
y are less sensitive to habitat fragmentation
n their fellow amphibians; and one American
d was observed eating over 1000 insects in
ngle day.
he photograph was taken in Scotts Run
ure Preserve, McLean, Virginia, by Bob Ford
n Frederick Community College, Frederick,
ryland, using a tripod-mounted Nikon D750
h a 55 macro lens.

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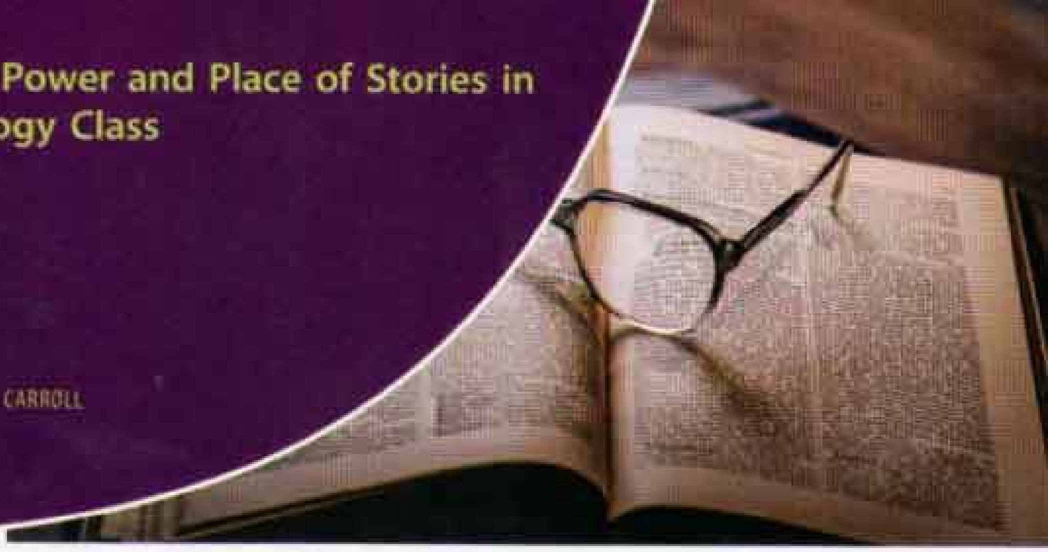
FEATURE ARTICLE

The Power and Place of Stories in Biology Class



SEAN B. CARROLL

Abstract

The universal appeal and pedagogical power of stories are well established, yet they are underutilized in biology classrooms. I suggest that stories have an important role in helping students understand how science is made, and in offering glimpses into the hearts and lives of scientists.

Key Words: *science teaching; story telling; creativity.*

> Tell me a fact and I'll learn. Tell me the truth and I'll believe. But tell me a story and it will live in my heart forever.
>
> — Native American Proverb

"All children, except one, grow up."

"In a hole in the ground there lived a hobbit."

"A long time ago, in a galaxy far, far away . . ."

Do I even need to say where these opening lines are from?

These phrases have been etched into our memories from the moment we first heard or read them. And how we love the stories they begin. The third quote is, of course, the first line of the first *Star Wars* movie in 1977, the start of what has turned out to be the largest grossing movie franchise of all time: thirteen films have earned more than 9 billion dollars and been seen by about 40 percent of American adults.

From Dr. Seuss to Disney, Harry Potter to Game of Thrones, we grow up and live in a world teeming with stories. In all forms of media—books, films, television, radio, and the internet—stories are the currency of everyday life.

> *Mark Twain said famously that the truth is stranger than fiction. One could add that the truth is stronger than fiction.*

Yet they are strangely absent from most science classrooms.

Despite a universal appreciation and thirst for stories, and considerable evidence for their pedagogical power, stories are underutilized in formal education, and in learning science in particular. One of my main goals as a scientist, educator, and storyteller is to encourage the use of stories in science education. Here, I will focus on two main questions: Why do stories have an important place in the science classroom? And, what makes for a good science story?

○ Homo Narrans

Rudyard Kipling once said, "If history were taught in the form of stories, it would never be forgotten" (1970). The author of *The Jungle Book* and the youngest writer ever to win the Nobel Prize for Literature (in 1907) certainly knew how to tell memorable stories. But he could not have known that in the ensuing century, a new branch of psychology would emerge that has amply confirmed his instinct about the power of stories.

One of the central tenets of "narrative theory" is that human thought is fundamentally structured around stories. People record and recall life experiences—their own as well as others' experiences—in the form of stories. This has been true since or before the dawn of civilization. Before the advent of writing, some reliable means was needed to transmit lore and information faithfully from generation to generation (Egan, 1989). All oral cultures, including those that survive to the present day, use storytelling. Stories typically embed content into vivid imagery and characters that inspire our imagination and arouse our emotions. No doubt our ancestors discovered that knowledge embedded in story form was more memorable. It has been claimed, and reasonably so, that story is one of the most important human inventions (Egan, 1989). Indeed, we are such storytelling and story-seeking creatures that numerous experts have dubbed our species *Homo narrans* (the storytelling person).

One important thrust of current research in this area is to understand why and how narrative plays such a crucial role in human

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FEATURE ARTICLE

Enriching Undergraduate Entomology Coursework through the Integration of Evolutionary Developmental Biology

HARALD PARZER, MATTHEW STANSBURY

Abstract

Evolutionary developmental biology (evo-devo) is a recently established discipline that connects evolutionary theory with developmental biology. However, despite evo-devo's integral use of diverse insect taxa as model systems and its interdisciplinary approach, current introductory entomology textbooks fail to fully integrate evo-devo into the undergraduate curriculum. We argue that an evo-devo case-study-based approach, focused on adult development, will not only familiarize students with exciting findings in this field, but will also help them deepen their understanding of basic entomological concepts. After a short background of the most important findings and methods currently used in evo-devo, we outline five case vignettes that span a variety of insect groups and entomological topics, including morphology and sexual selection.

Key Words: *entomology; evolutionary developmental biology; evo-devo.*

○ Introduction

Evolutionary developmental biology, popularly known as "evo-devo," is a recently established discipline that attempts to connect developmental processes with evolutionary theory (Raff, 2000). Although developmental biology and embryology were foundational to early evolutionary thinkers (e.g., with Ernst Haeckel's famous but flawed biogenetic law that "Ontogeny recapitulates phylogeny"; Gould, 1977), the rise of population genetics and the subsequent establishment of the "modern evolutionary synthesis" (Huxley, 1942) led to an essentially complete exclusion of development in our understanding of evolution. Despite the enormous success of the modern synthesis, it became clear by the 1970s that a full understanding of evolution could be achieved only with the reintegration of development into evolutionary theory, because it is the proximate mechanism that forms phenotypes upon which natural selection acts (Gould, 1977). However, given the limited number of existing molecular tools at that time, the successful unification of evolution and development – which Charles Darwin, Haeckel, and others envisioned – had to wait for almost two more decades, when major technological advances in molecular biology allowed scientists to begin uncovering the genetic underpinnings of plants and animals (Raff et al., 1999).

Evo-devo applies developmental genetics to answer the "how" questions in evolution.

Important molecular breakthroughs included polymerase chain reaction (PCR) and DNA sequencing, imaging techniques of gene and protein expression patterns (e.g., in situ hybridization and immunolocalization), as well as tools that allowed researchers to alter gene expression in a wide variety of organisms (e.g., RNA interference, or RNAi). While many of these tools were originally established in insect model systems such as the fruit fly *Drosophila melanogaster* and the flour beetle *Tribolium castaneum*, they have also been applied successfully to more morphologically interesting species, such as the aposematic milkweed bug *Oncopeltus* spp. (e.g., Angelini & Kaufman, 2005), the African butterfly *Bicyclus anynana* (Beldade & Brakefield, 2002), the horned dung beetles of the genus *Onthophagus* (e.g., Kijimoto et al., 2012), as well as the charismatic rhinoceros beetle *Trypoxylus dichotomus* (Emlen et al., 2012) and luminescent fireflies in the genus *Photuris* (Stansbury & Moczek, 2014).

In response to the considerable success of such studies, current introductory undergraduate entomology textbooks, such as the rightfully popular *The Insects: An Outline of Entomology* (Gullan & Cranston, 2014), have begun to dedicate special box-insets or short paragraphs to evo-devo, noting that "more detailed information on the genetics of morphological evolution are beyond the scope of an entomology textbook" (Gullan & Cranston, 2014). However, we argue that a more effective and efficient way of introducing evo-devo can be achieved by fully integrating its findings throughout the course, instead of dedicating a single lecture to it, thus emphasizing the interdisciplinary approach of evo-devo.

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