GUEST COMMENTARY

Amanda L. Glaze

Specialties & Perspectives Intersect to Tell Us What We Know about Evolution

Our world is so complex and interconnected, it is no surprise that science is too. This essay examines the multiple lines of evidence that align to provide our modern understanding of evolution and its mechanism.

Not surprisingly, Charles Darwin is often viewed as the primary (or only) source of our knowledge of evolution. Open any biology text and you will find a photo of the grand old man, something about the voyage of the *Beagle*, and a definition of evolution. However, our modern understanding of evolution is now so much richer because of a synthesis of evidence from intersecting specialties and perspectives. Just consider the following.

Paleontology (Stories That Fossils Can Tell). Evidence in support of evolution is often found within the layers of the Earth. From shells in the Andes to hominin remains unearthed from caves, fossils suggest both the appearance of and relationships between long-dead creatures. For centuries, naturalists and field scientists used observation and detailed field notes to provide us snapshots of living things long gone but preserved in the rocks.

Geology (Stories That Rocks Can Tell). Scientists have long used geological superposition – the notion that new rock deposits form on top of older rocks – to provide relative time comparisons of fossils. In addition to suggesting relationships by relative position, technologies such as radiometric dating provide a reliable timeline for the age of fossils that are found, allowing more evidence of orders of succession of life past and present.

Biogeography (Distribution in Space & Time). Building on fossil discoveries, geographers can make comparisons between organisms around the world based on their location. Biogeography specifically looks at where we find similar fossils and maps ranges of organisms. This mapping can be used to hypothesize timelines for migrations and demonstrate that some landmasses were once connected and even suggests the order in which the landmasses may have joined and separated.

Comparative Anatomy (Homology, Analogy & Vestigial Structures). Fossils offer exemplars for comparison to known organisms. Scientists have long used comparative anatomy to explore structures in living and extinct forms. This idea of "descent with modification," that similarities among organisms can be explained by small changes over generations, was described by Darwin, for which he is often under-credited. Close examination of structures and functions allows us to make hypotheses about relationships between organisms that have evolved within the same line (homologs) or evolved in a similar way in different lines (analogs). We can also observe remnants of traits found in ancestral species that have slowly become less useful (vestigial structures), like hind limbs in whales and the human appendix.

Comparative Embryology (Developmental Relationships). Building on our understanding of comparative anatomy, we have the ability to examine structure and function on a more intimate scale through comparative embryology. Examination of the earliest cellular states of living things can provide evidence of evolutionary relationships and even the degrees of separation of living things based on when specific traits appear in development.

Genetics (Stories in the Genes). Darwin understood inheritance – after all, he was a pigeon breeder – but he had no knowledge of genes. The advent of genetics and related biochemistry allows us to understand the details of descent with modification and the bigger picture of diversity. Bones can suggest evolutionary history, but genetic material recovered from those bones is useful in confirming hypotheses about speciation and relationships. The ability to "look within" began with comparative anatomy and fossils, but our present understanding is confirmed on the genetic level. Evolutionary study of living organisms has demonstrated the impact of gene flow and reproductive isolation on speciation, while cladistics and "tree thinking" take us beyond comparison of homologous and vestigial structures to DNA to verify proposed relationships, ancestries, and when speciation occurred.

Cultural Anthropology (The Story That Makes Us Human). As Darwin stated in *Origin of Species*, "light will be thrown on the origin of man and his history." As much as we learn from bones and stones, the evolutionary story of life, human and otherwise, now encompasses social elements with the scientific. Diet, culture, art, beliefs, and other elements of modern and historical human behavior greatly inform the narrative of modern humans. While physical anthropology is focused on the stories told by fossils, cultural anthropologists explore cognitive evolution by exploring behaviors such as burial practices, shared belief systems, social structures, and communication. This intersection of applied and social sciences builds our understanding of who we are.

Observations in Real Time (Evolution in Action). A principal anti-evolution argument is the notion that we can't confirm the historical record because we were not there to witness the events. While inference tells us much, the argument that evolution cannot be witnessed is false. Evolution as evidenced through descent and speciation are observable firsthand and on very modest timescales. Some groundbreaking examples of this are found in the work of Rosemary and Peter Grant with the Galápagos finches, the work of David Reznick with Trinidadian guppies, and on a long-term scale with the work of Richard Lenski on *E.coli*, just to name a few.

Synthesis: A Hallmark Trait of Science. Darwin was a man of great vision and a quintessential scientist. He moved easily between various fields of study in his quest for understanding. All who study evolution are following the same method by synthesizing evidence, data, and explanations from a wide range of fields and perspectives, thereby demonstrating that evolution is the best possible explanation for the unity and diversity of life.

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