Are We Not Dinosaurs?

A STORY OF DARWIN, EVO-DEVO, AND THE OUROBOROS OF AVIAN GENEALOGY

By Arielle Johnson

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As anyone who got their dino-science from Dr. Alan Grant knows, before there were chickens (or chicken eggs), there were dinosaurs. And no bird is more closely related—on a genetic level—to the attractions at Jurassic Park than Gallus gallus domesticus, or chickens (and, fine, turkeys, too). Of the roughly 10,000+ modern species of birds, the chicken is by far the most populous and husbanded. At any given point, there are about 20 billion egg-pumping creatures of today? So how did we get from T-Rexes to the beady-eyed, massive-breasted, egg-pumping creatures of today? Much of the answer is in beak shape, was naturally confined to its own semi-isolated island. Pondering this geographical-morphological relationship—that the species were related to each other, but each adapted to their own specific locality—as well as other phenomena he'd uncovered sent him down a rabbit hole of theorizing and background research further afield. But as critical thinkers poked holes in these arguments, he found, naturalists were increasingly able to correlate fossil depth to successive periods in time and refine the relationship between fossils and living organisms.

The discovery and study of dinosaur fossils really took off around the turn of the 19th century, and it quickly became clear that at some point in the past, the world was dominated by gigantic reptiles that had since totally disappeared. Darwin himself had used mammal fossils from South America—extinct giant sloths and armadillos—in developing the basic arc of the theory of evolution. With dinosaurs, a big question remained—how did we get from giant reptiles to the animals we have today? The connection between dead giant sloths and living, regular-sized sloths was obvious enough. But if scientists went back far enough in the record and found dinosaurs but no birds or mammals, and evolution was true, then WTF happened?

When Darwin released On the Origin of Species in 1859, he recognized that an obvious consequence of evolution was that “if species have descended from other species by insensibly fine gradations, do we not everywhere see innumerable transitional forms?” He explained that the lack of obvious living transitional forms was probably because evolved species replaced their original lineages, and hedged that transitional fossils weren’t being found “embedded in countless numbers in the crust of the earth” because...
fossils are really hard to make and in the grand scheme of things, only happen very rarely. “The crust of the earth is a vast museum,” guys, “but the natural collec-
tions have been made only at intervals of time immemorably so,” chill out with the transitional fossil demands.

Then, 2 years later, a new find gave naturalists a frisson of excitement and vindication. In a limestone quarry in Bavaria, a dino-
saur-ish fossil German naturalists called the Urvogel (“first bird”), and later became known as the Archaeopteryx (“Ancient wing”) was excavated. It was roughly the size of the raven and had, like most dino-
saurs, a long tail, a jaw full of teeth, and a flat sternum. It also had a wishbone, some hollow bones, downy feathers all over its body, and wings covered in asymmetrical flight feathers. In other words, it was an obvious transitional link between dinosaurs and birds. Darwin’s buddy Hugh Falconer, who’d seen the fossil when it was presented at the Royal Society in 1841 (it was a reclusive, so stayed home), wrote him thus: “Had the Selenhofen quarries been commis-
sioned—by august command—to turn out a strange being a la Darwin—it could not have executed the heist more handsomely—
than with the Selenhofen fossil.”

It took another century-plus for the sci-
centific community to finally agree, but eventu-
ally the idea that birds evolved from dino-
saurs made its way into high school science classes everywhere. Except Kentucky.

THE UR-CHICKEN, OR, THANKS AGAIN, DARWIN

It’s now widely accepted that the chicken is (mostly) descended from a bird called the Red Jungle fowl, which looks like the bug-eyed, wily, cousin of the birds we see at farms, and which has a natural range in south and southeast Asia, from northern India in Tamil Nadu south to Malaysia, the Philippines, and Indonesia. This connection, it turns out, is another of Darwin’s great gifts to chickenology. Harkening back to his earlier inspiration from the chicken and other domestic animals—post “On the Origin of Species” and pre “Descent of Man,” Dar-
win made a deeper exploration into artificial selection called “The Variation of Animals and Plants Under Domestication,” where he fleshed out the argument for the Red Jungle Fowl as the progenitor of the modern chicken. Carolus Linnaeus, the father of modern taxonomy, was perhaps the first Western naturalist to classify the chicken as a rela-
tive of the red jungle fowl. Technically, the domestic chicken is classed as a subspe-
cies (Gallus gallus domesticus) of the red jungle fowl (Gallus gallus) and a relative of other Gallus species, all of which are differ-
tent kinds of jungle fowl. Linnaeus wasn’t advancing an argument about ances-
try—evolution was not really a thing in the 1700s, and most natural philosophers (what we called scientists in the early Enlighten-
ment, when we were still inventing the idea of science) were creationists. Their goal was to catalog the animals God created in Genesis and their relationships (“God created, Linnaeus organized”) is one of his famous humble-
bragging statements. Obviously God had created both the chicken and the jungle fowl, and made them able to breed; thus, they were both Gal-
lus gallus. Darwin, who’d seen the new hybrid, noted that by breeding a purebred black Spanish cock with a harem of hens, most of which were white or black and white, and none of which had shown in their breed lines the characteristic red/orange-shouldered, blanched long tail— tallying up to the looks of the red jungle fowl. Despite their achromatic parentage, many of the result-
ings by breeding a purebred black Spanish cock with a harem of hens, most of which were white or black and white, and none of which had shown in their breed lines the characteristic red/orange-shouldered, blanched long tail, the resultants had developed red hackles and shoulders and dark bod-
ies—reverting to ancestral characteristics, according to Darwin.

Rounding out his breeding experi-
ts and ornithological analysis, Dar-
win also drew creatively on scholarship from the humanities as a record of evi-
dence. Darwin longed for a larger, more evoca-
tive vocabulary than the Greeks called chickens “Passer,” but since no chicken-like wild birds had a nat-
ural range that included Persia, they prob-
ably came to Greece from somewhere fur-
ther east via Persia, that the etymology of words for chickens in Asian languages suggested that the word, therefore also the bird, may have originated in Malay-
sia or Java, and that recently-translated ancient Chinese texts recorded chickens being imported into China in the 1400s BC. Darwin also cited the Bible as evidence, since chickens are mentioned in the New Testament but not in the Old.

The continued professionalization of the gentlemanly pursuit of antiquarian-
ism into the social science of archaeology fleshed out the early history of the spread and differentiation of the chicken through-
out the ancient world. But after Darwin the debate over the primary origin of the chicken stalled until the 1990s when the rapid development of molecular biology and molecular genetics, fields in which precise chemical analysis of invisible components of life—like DNA and proteins—allowed sci-
entists to make con-
tentions and tell new stories about the rel-
ationships between organisms over long stretches of time and across wide spaces in geography. Intensive studies of the genetic sequences of modern chickens, ancient chicken bones, and various wild jungle fowls, especially considered in tan-
dem with archaeological, linguistic, and historical evidence, have enriched, compli-
cated, and sometimes muddied the picture of where and when the jungle fowl became the chicken.

Genetic studies suggest that a key fea-
ture of most modern chickens—their yel-
lowish skin—could not have come from red jungle fowl, which have whitish skin. The gene that makes pigments from the chicken’s diet show up as color in the skin doesn’t exist in red junglefowl, but does in grey jungle fowl, a chicken parentage that Darwin had ruled out. Bone analysis from a site in northern China suggests that domesticated chickens were found much farther north (in a climate where no jungle fowl now live), and of much earlier origin (as early as 7-10,000 years ago, or, 5-8,000 BC, than anyone expected. Was this the product of an earlier domestication-
et event, outside the current range of the red jungle fowl, that then spread south-
wards? Or was the chicken domesticated multiple times in parallel? Or, as has been sug-
gested, that many domesticated chicken breeds were derived from a common ancestor, a species that had not been available to a similarly-ed-
eligated Naturalist of a generation or two before. In addition to extensive com-
parisons of appearance and analysis of reported data from chicken and jungle fowl observers in Asia (the aforemen-
tioned educated white dudes), he also approached the question empirically, through breeding experiments.

He was happy to report that, of the wild jungle fowl species in Asia, the evi-
dence showed that only Red Jungle Fowl could produce non-sterile offspring with chickens (a phenomenon that’s currently edging the red jungle fowl towards extinc-
tion as a distinct species)—rather than dying out, it interbreeds so much with domestic chickens that it’s become tricky to find a red jungle fowl with only wild genetics), this unique interbreeding abil-
ity edging it up as the most likely ancestor. Putting his chicken-fancying-specimens to the British breeding industry, he concluded, in re-
ings by breeding a purebred black Spanish cock with a harem of hens, most of which were white or black and white, and none of which had shown in their breed lines the characteristic red/orange-shouldered, blanched long tail, the resultants had developed red hackles and shoulders and dark bod-
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Darwin himself didn’t know what the human forerunner of every modern chicken, currently didn’t know about genes, with genetics not really established as a sci-
sence until the early days of the 20th century; or DNA, which wasn’t understood until after Darwin’s death and was not discovered until the 1940’s. Now we know that evidence is due to random mutation at the molecular level of DNA, if the mutation helps with adaptation to its environment, or makes it easier to its prospecutive mates, then that mutation is passed on. Of the differences in particular feathered chickens come from random mutations that humans decided to propagate. When feathers are bred together, the new hybrid gets genetics from its parents each gen-
teration, some at random, some that humans have already selected and sometimes muddied the picture of where and when the jungle fowl became the chicken.
LUCKY PEACH CHICKEN

From Sebright’s bantams into chicken fancy, Darwin's breeding experiments, and beyond, artificial selection accelerated the evolution of the chicken in the 19th and early 20th centuries. Around this time, there was interest in “improvement” of breeds to make them grow larger, faster, more efficiently, or lay more eggs, and rearing flocks specifically for egg laying became common (with the male chicks in these flocks used as “broilers” or meat chickens), especially after the first world war. But that was peanuts compared to the ways chickens have been changed in the decades since World War II.

Chickens have, over successive generations of selective breeding, been transformed from a variety of heirloom breeds that gave both eggs and meat into an industrial bioreactor for turning corn into protein, as efficiently as possible. With these chickens you can choose eggs or meat, not both. And you certainly don’t get to choose flavor. That’ll be $7.

The infamous Chicken of Tomorrow contest of 1948 marked a watershed moment in the creation of the industrial breeds that make up most of the chickens alive today. It started innocently enough—with beef being rationed during the war, Americans’ chicken consumption almost doubled, and grocers were interested in keeping sales up. A&P started a contest for chicken breeders of all stripes—young, old, professional, amateur—to submit for consideration their attempt to create a bird that, in 12 weeks and on the least possible food, created the largest, most breasty, picture-perfect specimen. The winning chickens were an hybrid, the first generation of a cross between a Red New Hampshire Hen and a California Cornish Rooster.

At 12 weeks, they weighed 3.75 pounds each; this was an improvement compared to the average chicken of 1943, which at 12 weeks weighed only 3 pounds. Part of their success came from a phenomenon called heterosis or hybrid vigor, which is the tendency of the offspring of two parents, each from a different inbred or heirloom line, to have biological enhancements (like size, strength, or uniformity) compared to their parents.

The selective breeding continued over subsequent years, expanded from grocery chains to university animal science departments and commercial chicken breeders, and by 1973, chickens destined to become meat were reaching maturity at 8.5 weeks. It’s now possible to rear chicks that reach maturity even faster, in 5 weeks, and put on 4 pounds and change in that time.

A few other developments besides intensive breeding helped make this possible. The 1960s and 70s were the first decades of the heyday of cheap corn, thanks to intensive farming methods, commercial seed lines, and selective breeding. Previously, “free-range” chickens weren’t a thing because all chickens were free to range—and even if they were fed largely on grain-based chicken feed, they roamed around outside and could eat grasses, insects, grubs, and other miscellaneous sources of food to round out their diets.

Chicken farmers actually had to let their animals forage—if they didn’t, they got metabolic diseases (similar to rinderpest and avian influenza in humans) from missing the micronutrients they would usually get from their grub supplements.

This brings us to the third element of the commercial chicken trifecta: the “vital essences” or vitamins and minerals discovered in the early part of the 20th century, the molecular characterization of the compounds responsible for limes being able to cure scurvy (vitamin C), and brown rice curing beriberi (vitamin B1), among others. With these isolated micronutrients in hand, chicken farmers could fortify inexpensive corn, and create a feed that fattened chickens quickly without killing them. This allowed producers to go from 50-200-chicken flocks to facilities with thousands upon thousands of chickens, since there was no longer any need to let chickens out onto pasture to keep them alive.

And just like that, you’ve got a recipe for billions of giant, inexpensive, tasteless chickens, with no GMOs necessary.

CHICKENS OF FUTURE PAST

And as for chickens and dinosaurs, we’ve barely gotten started. We know that as the saurischian class of dinosaurs evolved throughout the Triassic and into the Jurassic period, a branch of ancestrally carnivorous theropods emerged as hindlimbs. They have a tail where a chicken has a stump structure called a pygostyle, a jaw where with a chicken has a beak, and their 5-fingered front limbs differ from a chicken’s 3-appended wings, though those wings develop in the chicken embryo from hand-like structures.

But the basic map of a vertebrate isn’t reconstructed—animals forage—if they didn’t, they got metabolic diseases (similar to rinderpest and avian influenza in humans) from missing the micronutrients they would usually get from their grub supplements.

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are found with extremely similar sequences throughout the animal kingdom (fruit flies, chickens, and humans alike).

But, crucially, the HOX genes don’t code for legs or wings—the proteins they code for bind to other sections of DNA, and by binding, turn those genes off and on. The genes that HOX proteins bind to don’t code for a leg or a wing either: they in turn code for proteins that control other genes, the coordination of which eventually leads to bone or eye (or wing or tail) development. HOX genes, and the genes that HOX proteins bind to, are called transcription factors: they control what sections of DNA get read and transcribed into RNA, which then gets translated by the ribosome into a protein. An organism can easily have dozens of transcription factor genes, each of which can bind to and regulate a hundred or more target genes. And the target genes might code for a specific enzyme or type of tissue, but just as often they are also regulatory genes, so what gets switched on or off is yet another cascade of switching.

IF IT SOUNDS COMPLICATED, IT IS!

But the basic takeaway is that the big physical differences in, say, a bird and a dinosaur don’t actually come from direct changes in the genes that directly build the tail or wing, but in genetic changes that affect the regulation of those genes. Which means that the changes in dinosaurs that led, eventually, to the chicken, were regulatory: downregulation of tail development, changes in forelimb development that mutated hands into wings, changes in the genes that direct the locations where feather follicles develop, and inactivation (but not necessarily deletion) of genes that cause tooth buds to develop, among others.

Some people (probably most of you) will take this as an interesting food for thought or factoid for your next dinner party, or take it as an opportunity to get philosophical with yourself (“All human beauty comes from arbitrary differences in the regulation of cells that make structural materials, and the face that gives me my social currency is just an emergent property of transcription factors making slight differences in bone secretion rates in cells in different locations! My idea of myself is an illusion! Society is a sham!”). A paleontologist named Jack Horner is taking it and running with it—backwards in time. He looked at evo-devo and decided that if we know how gene regulation changed tooth into beak formation in the chicken embryo, then, we can just as easily regulate in the other direction, creating “experimental atavisms”, causing a chicken embryo that natively has the code for a beak to develop teeth. And we can do the same for other regulatory pathways—stimulating the embryonic chicken’s pygostyle to develop into a tail; swooping in and downregulating the growth of the long digits that make up the wing, thus creating a hand instead; and altering the regulation pathway that directs where feathers develop.

You’d think that, as the science advisor for Jurassic Park (he was, really really, the paleontology advisor for both the book and the movie), Horner would know better—Life Finds A Way, after all, and rarely are the results clean or predictable—but he’s forging ahead, working with evo-devo labs who study the pertinent regulatory networks in embryos. When and if they create an embryo that can actually grow (remember the scene in Alien Resurrection where Ripley finds all the horribly mutated, earlier attempts to clone her? That’s basically what an evo-devo lab’s archive looks like, wrt chicken); it remains to be seen whether their ethics oversight committee will let them hatch it.

But, in a postmodem ending to the story of chickens, as a common, genetically understood bird, they are the standard avian model organism, and thus the natural subject of Horner’s reverse evolution. What came from dinosaurs through jungle fowls, chicken fancy, and Darwin’s research into the modern chicken is starting to loop the evolutionary tree into a circle, taking us to dinosaurs once more.