**Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_ Hour:\_\_\_\_\_**

**B5.1B** *Describe how natural selection provides a mechanism for evolution.*

April 14, 2009, 8:49 am

<http://tierneylab.blogs.nytimes.com/2009/04/14/should-we-build-a-dinosaur/>

# Should We Build a Dinosaur?

By [JOHN TIERNEY](http://tierneylab.blogs.nytimes.com/author/john-tierney/)

When I endorsed the idea of [resurrecting a Neanderthal from DNA](http://tierneylab.blogs.nytimes.com/2009/02/13/why-not-bring-a-neanderthal-to-life/), I was a little surprised at how many indignant [angry/resentful] comments it inspired. I’m not sure how representative that reaction was — there could be a selection bias for indignation when posting comments — but I’ll assume there are a fair number of people who don’t like the idea of recreating extinct hominids [early humans].

Then how about Jack Horner’s scheme to build a dinosaur?

No, this is not a Jurassic Park fantasy involving some recovered bit of prehistoric DNA. Dr. Horner, a paleontologist at Montana State University (and, incidentally, a consultant for the “Jurassic Park” movies), is one of the scientists who have detected similarities between dinosaurs like Tyrannosaurus Rex and the modern chicken. By biochemically manipulating a chicken embryo to “awaken the dinosaur within,” researchers at McGill University are already studying ways to get the embryo to grow a dinosaur’s tail. Eventually the scientists hope to see a “Chickenosaurus” hatch with tail, teeth and forelimbs instead of wings.

Dr. Horner explains this project in a new book, [“How to Build a Dinosaur: Extinction Doesn’t Have to Be Forever,”](http://us.penguingroup.com/nf/Book/BookDisplay/0%2C%2C9780525951049%2C00.html?How_to_Build_a_Dinosaur_Jack_Horner) co-written with James Gorman, the deputy science editor of the Times. The contrarian [person who always disagrees or puts down an idea] in me would love to come up with a reason to oppose any project favored by my editor, but after my build-a-Neanderthal advocacy I’m having a hard time coming up with a decent reason not to build Chickenosaurus. Perhaps some Lab readers could give me cause for indignation. But before you do, consider a couple of pre-emptive answers to some commons objections, as provided by Dr. Horner:

Suppose you hatch a Chickenosaurus? What good is it?

It would get a lot of attention if you walked it on a leash, and it would be better than a slide show for demonstrating evolution.

In terms of research value, in order to turn a chicken into Chickenosuarus we would have to reverse evolution. That can teach us a tremendous amount about how evolution works. It would show how small changes in the development of an embryo can make for big changes in what the adult looks like.

But is there any practical benefit? Why not spend money on cancer research instead of turning chickens into dinosaurs?

Research is unpredictable. Finding out the structure of DNA and how genetics works has taught us a lot about disease and promises to revolutionize medicine. The goal of the researchers was to answer basic questions about biology.

But we already have some idea of how this might be practically useful. The growth of the tail is tied into the problem of the spinal cord, and spinal cord birth defects in human are a major medical problem. Learning more about what prompts and stops tail growth could give us important insights about serious human birth defects.

Whatever practical spinoffs there might be from this project, to me it seems worthwhile simply for the value of reviving and observing extinct creatures. But as I say, I’m open to causes for indignation. You can read more details of Dr. Horner’s plans at [Discover magazine](http://discovermagazine.com/2009/apr/27-jack-horner.s-plan-bring-dinosaurs-back-to-life). Or you can wax eloquently right away.

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1. What do you find most intriguing/interesting about the prospects/potential of having a pet dinosaur?
2. **(B5.1B)**Using the idea that a new species or variety of organism originates [come into existence/being] through the evolutionary process of natural selection, how could you use Natural Selection to explain the existence of birds? Consider what we have learned about reptiles, birds, and dinosaurs.

# <http://discovermagazine.com/2009/apr/27-jack-horners-plan-bring-dinosaurs-back-to-life>

# Jack Horner's Plan to Bring Dinosaurs Back to Life

#### The world's most famous dino-hunter says the key is embryonic development, not genetics.

By [Jack Horner](http://discovermagazine.com/authors/jack-horner), [James Gorman](http://discovermagazine.com/authors/james-gorman)|Friday, March 27, 2009

[Hans Larsson](http://redpath-staff.mcgill.ca/larsson/) is a fast walker and a fast talker. You need to be fit to keep up with him on the hills of the McGill University neighborhood in Montreal, let alone on the remote islands of the Canadian Arctic where he searches for fossils in summer fieldwork. He talks the way he walks, in a freely swinging fast-paced lope that ranges from the philosophy of science to genetic probes to the rich Cretaceous ecosystem he is exploring at another field site in Alberta.

Larsson is at the forefront of merging paleontology and molecular biology in an effort to connect major evolutionary changes—the development of new species and new characteristics, new shapes and structures, new kinds of animals—to changes in specific genes and in how those genes are regulated. He is interested in reactivating dormant genes or changing the regulation of active genes in embryos to bring back ancestral traits that have been lost in evolution.

Scientists can do this now because we have the fossils. We have the lessons of developmental biology. And we have the tools of molecular biology. All of these are being merged in the study of the history of life in evolutionary developmental biology, or [evo devo](http://discovermagazine.com/2009/mar/19-dna-agrees-with-all-the-other-science-darwin-was-right).

Collecting and cataloging fossil bones, the heart of vertebrate paleontology, has been primarily a historical enterprise, one of unearthing ancient information and looking for patterns. Laboratory science has been conducted in a different fashion. You could suspect, say, that a gene that controls a particular growth factor is important in how five-fingered hands develop at the ends of arms. So the hypothesis might be that if that gene were absent or nonfunctional, the hand would not develop. You can engineer mice so that the gene is absent or silenced and see what happens to the development of the embryo. If the hand develops perfectly, your hypothesis is false. If the hand does not develop, you have good evidence that the gene in question does what you thought it did.

What about a significant change in form? What happens that allows something new to be introduced that hasn’t been seen before in evolution, something like the appearance of limbs, or hair, or feathers, or lactation? We can see it happening on a gross anatomical level throughout the fossil record, but how can we test in the laboratory our ideas about what went on at the molecular level?

There is a way that these ideas can be tested, but it takes us to the very edge of science. The trick is to run the tape of evolution over again: to intervene in the development of a chicken embryo, for instance, to reverse evolution, rolling back the clock to manifest [show] earlier patterns of gene expression. This is a profound advance in the kind of experiment available to test evolutionary theory, and it depends entirely on the progress that has been made in evolutionary developmental biology. It is only because we can match developmental events to evolutionary events, only because we now have both the [fossil record](http://www.fossilmuseum.net/fossilrecord.htm), which shows us the path that evolution has taken, and the developmental record of modern animals in extraordinary detail, that we can begin to link the two.

With birds, for instance, the absence of a tail, the difference between wings and grasping forearms, and the absence of teeth are all subtle evolutionary changes on a basic dinosaur plan. Why not rerun an ancient developmental process in a bird embryo, this time triggering the signals to produce a grasping forelimb or a long tail?

At last, we would have a truly experimental way of studying macroevolution, the kind of changes that lead to the creation of new species. If we think a particular process is responsible for the origin of feathers, we could rerun that process, changing the developmental pathway in the bird embryo as a way to test our proposed evolutionary pathway.

But why stop at one developmental process? Why not grow an entire dinosaur? At least that’s the thought that came to my mind. It seemed so obvious that if fairly small changes in development, which adjusted the timing and concentrations of growth and signaling factors, could have led to the evolution of birds from nonavian dinosaurs, we could readjust those changes in development and get a dinosaur from a chick embryo. Dinosaurs and chickens share a very similar skeleton. In the grand scheme the differences between the two creatures are just adjustments to a basic body plan, and such adjustments, we are assured by evo devo, are the result of changes in gene regulation, not a complete new suite of genes. Once I got the idea in my head that it could be done, I started talking to researchers who were truly fluent in the language, ideas, and techniques of both paleontology and molecular biology. That’s how I ended up talking to Larsson.

He was already researching how the tail in birds first got shorter and then disappeared over the course of evolution. I thought, why not look at it from the other direction? Suppose we were going to try to bring back the tail—what would we do then? I gave about 40 thousand dollars to pay for a postdoctoral researcher to work on this problem in Larsson’s lab. Larsson is continuing to pursue the research on his own now.

A very few experimental attempts to achieve this kind of thing have been done. Chicken embryos have been induced to grow teeth without any transplant of tissue from another organism. Changes in the presence of growth factors produced the teeth, which were consistent with those of [archosaurs](http://www.ucmp.berkeley.edu/diapsids/archosauria.html) (the group that includes birds, nonavian dinosaurs, and crocodilians).

Primitive birds, like [*Archaeopteryx*](http://en.wikipedia.org/wiki/Archaeopteryx), [had tails](http://findarticles.com/p/articles/mi_m0EPG/is_n10_v30/ai_18704753), but modern birds don’t. It seems a good bet that this was a simple evolutionary change at the molecular level, a turning off of the growth program that was keeping the tail going. Find the chemical switch, flip it the other way in embryonic development, and the result would be a bird with a tail. Larsson determined that in chicken embryos, a tail does begin to grow in the normal course of events. But then, he said, “I found that at a particular stage of development everything comes crashing to a halt.”

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**Hi, Mr. Cistaro here.**

**I want you to take a moment and look at this chart. DON’T LOOK AT THE BOTTOM. Just looking at the top row, can you tell which one is human? What about just picking out which one(s) is/are mammals?**

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Larsson and his postdoctoral assistant began to try to make an embryo’s tail continue growing. They began snipping off the tip of a growing tail at one stage and stapling it, with fine tungsten wire, to a later stage, to see if the growth factors in action during early tail growth could override the stopping signals. The next step was to add retinoic acid, a compound that stimulates the release of a protein called sonic hedgehog [This is not a joke! Well, it kind of is, but this is the real name. It turns out if you discover the gene or protein, you get to name it.], which is important in promoting growth during development.

Transplanting completely failed to keep the chick embryo’s tail growing, but the retinoic acid, Larsson said, “pushed tail growth to the upper range of normal development. It had some effect, but it didn’t break it out of the cycle.” The tail was a far more complex system than he or anyone else had imagined.

The initial hint of growth from the retinoic acid was encouraging, but Larsson needed to know much more. In particular he needed to avoid creating something that looked like a longer tail but was simply an embryologist’s trick, a growth that occurred without utilizing an ancestral pathway. Unless he knew the normal pathway of development in detail, all he would have achieved with a tailed chicken would be a circus attraction.

Unfortunately, there was no foundation of basic research describing how a tail grows. Studies had been done on how embryos initiated tail growth, but not on how they maintained that growth and what genes might be involved. Larsson had to start from scratch and do fundamental developmental research.

Larsson is now working on a model of how the tail grows. This will involve labeling cells in the growing embryo tail and using microinjections of dye to follow the pathways that these cells take as the tail develops. His goal is to see how zones of growth and organization move as the embryo grows and to probe what is going on biochemically. He has been able to piggyback on previous work on the development of the chick embryo: When researchers interested in some process use a stain to show gene activity, the stain affects the whole embryo, providing clues about which genes are active in tail growth.

Although the growth of the tail is very complicated once begun, the action that turns that growth off may be quite simple. Larsson compares the situation to a mechanical one. “It’s kind of like the key to a car. You could turn the key on and the motor will run and produce all these patterns and rhythms. Once you turn the key off, it stops. The key is relatively simple, compared with the rest of the car. I think that’s the kind of system we’re dealing with. Or I’m hoping.”

But building a dinosaur requires more than just a tail. “The experiment I’m envisioning is that you have a single embryo developing in the egg with multiple injection sites and multiple kinds of molecules to be really fine-tuning the regulation of genes,” Larsson says. “We’ll be able to inject different parts of the embryo at different times of development with different things. If we do that, if the timing and position are correct, we should be able to manipulate lots of different kinds of morphologies—feathers, wings, teeth, tails.

**We don’t have to give an embryo new genes, just adjust the growth factors and other chemicals that direct development. It would be the first step in growing a dinosaur.**

“It would take just a little bit of time to work out each one of those systems in very great detail, which we’re now doing for the tail. Other people are doing it for the limbs for clinical work. And teeth are being worked out by other people for mammals and such, and then we can just sit down and play with all these in concert, which has never been done before.”

The goal, in the end, would be to steer the embryo down the path it would have gone if it were something like a very early [coelurosaur](http://www.ucmp.berkeley.edu/diapsids/saurischia/coelurosauria.html), a dinosaur grouping that counts tyrannosaurs and velociraptors among its members. If the genes in the chick embryo are very close to those of an ancestral, nonavian dinosaur—and if the changes, over more than 150 million years, have been almost all in regulation of the genes—then we could reactivate the old pattern of regulation.

We don’t have to give the embryo new genes, just adjust the growth factors and other chemicals that direct development. And by doing that we can see what must have changed during evolution, and what the old pattern of regulation was. If we learn enough, this will give us enormous insight into the fundamentals of biology, development, and evolution. It will also be the first step in growing a dinosaur.

In the end, there is an image that keeps popping into my mind. I give an awful lot of lectures. I don’t read from notes; I prefer to use slides, each of which fits with a topic that I want to talk about. I don’t need to memorize a speech or make it formal. I can stay conversational, which is what I find most comfortable.

So the image I have is that I walk onstage with a dinosaur on a leash. It’s small, but bigger than a chicken. Let’s say it’s the size of a turkey, one day maybe even the size of an emu. The dinosaur, or chickenosaur, or dino­chicken, the emu-size version of a dinosaur (that one might have a muzzle or a couple of handlers) is the ultimate slide. Instead of a lecture, this would be a public science class with questions and challenges about how it was done, what its skin feels like, does it have teeth, what does it eat, how close is it really to a dinosaur? What would inevitably follow would be a discussion about the nature of dinosaurs, of birds, of evolution and development, of the relationship of molecular biology to big changes in evolution, of how we know what we know, and whether we were justified in doing what we did.

That would be the most satisfying lecture I could possibly give. I don’t like providing answers. I never have. I like questions. I like asking them, trying to figure out answers, trying to figure out what we are really asking, and seeing what new questions come up. For this event I won’t have to prepare any speech at all. My entire prepared text will consist of one simple question from which everything else will follow.

I’ll walk to the edge of the stage, point to the creature on the leash, look at the audience, and say, “Can anyone here tell me what this is?”

*From* [*How to Build a Dinosaur*](http://www.amazon.com/How-Build-Dinosaur-Extinction-Forever/dp/1400111412)*, by Jack Horner and James Gorman. Published by arrangement with Dutton, a member of Penguin Group (USA), Inc. Copyright © Jack Horner and James Gorman, 2009.*

1. What would you name your protein/gene? Pretend you found the gene for hairy legs, what would you call it? Why?
2. **(B5.1c)** Reflecting on the article and the picture I gave you, could you **s**ummarize the relationships between present-day organisms and those that inhabited the Earth in the past (you could use the fossil record, embryonic stages, homologous structures, or some chemical basis)?
3. **(B5.3f )**What applications/treatments/reasons did the scientist give for why this work was important? Or to put it another way, how does this demonstrate and explain how biotechnology can improve a population and species?