Chicken revisits its dinosaur past

If we can rewind evolution to create a "snouted" bird, we might also be able to fast-forward it

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ARHAT ABZHANOV cuts a square hole in the shell of a chicken egg, drops in a small gelatinous bead and watches the embryo develop. By day 14, the chick has formed not a beak but something more snoutish – a feature, he says, "modern birds have not seen since the Cretaceous". Abzhanov has rewound evolution.

Chickens share a common ancestor with alligators and are descended from dinosaurs, raising the question of how they and other birds switched from snouts to beaks. Because chick and gator embryos start out looking strikingly similar, Abzhanov, an evolutionary biologist at Harvard University, suspected the key might be found in developing embryos. In his open-egg experiment he tweaked a few of the embryo's genes to make them behave more like identical genes do in an alligator embryo.

If rewinding evolution has a certain Frankenstein-esque quality, the opposite is even more intriguing. Fast-forwarding evolution to create the chickens of the future may also lie within grasp. And that, in theory, could lead to the creation of species better equipped to handle a changing climate.

Mounting evidence shows that small modifications in when and where genes are switched on are all that's necessary to trigger dramatic shifts in anatomy. These changes can lead to the appearance of beaks, turtle shells and jaws (see "Qucks and duails").

"Small changes in when and where genes are switched on may trigger dramatic shifts in anatomy"

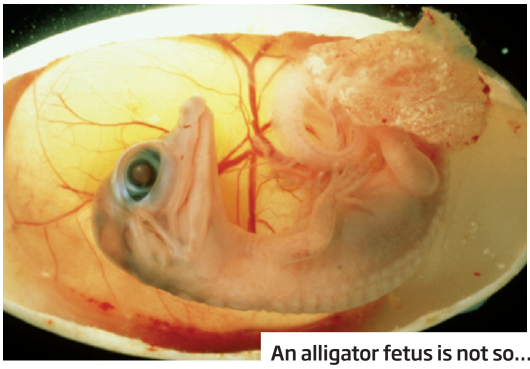
Generally, the genes that control these major anatomical changes produce signalling molecules. In a developing embryo, these switch on genes controlling the formation of structures such as limbs, organs and facial features. Other genes dictate where the molecules are produced and therefore where they take effect, ensuring that embryos don't grow digits in the wrong places, misshapen bones or an extra pair of eyes.

CARY WOLINSKY/AURORA/GETTY

Abzhanov's "snouted" chicken provides a striking demonstration of just how easy it can be to provoke major evolutionary changes, says Craig Albertson, a developmental biologist at the University of Massachusetts in Amherst. Before such experiments were possible, explanations for how creatures evolved "relied on the fossil record, which is incomplete, and mathematical modelling, which is boring".

So how did he do it? Abzhanov started by trying to pinpoint the gene changes that led to the myriad beak shapes of Galapagos finches. In 2004, he showed that all the finches share a handful of genes crucial to beak development, but instructions for the signalling molecules they control vary from bird to bird (*Science*, vol 305, p 1462). Abzhanov realised that a similar process might underlie the much bigger evolutionary shift from snouts to beaks.

The tip of an alligator snout is made of a separate set of paired



An alligator fetus is not so...

...different to a chicken fetus

L TO R: NEIL BROMHALL/OSF/GETTY OSF/GETTY

Back to the Cretaceous

bones called the premaxillary, but in birds, these have fused with the main of the upper jaw to form a single, sharp bone.

Abzhanov scanned signalling molecules in alligator and chick embryos and found that two of them – known as sonic hedgehog and fibroblast growth factor 8 – show up before the snout and beak form. In gators, however, the molecules were only present along the sides of the face. Chicks express them both at the sides and centre of the developing face. What would happen, he wondered, if he turned that central expression off?

He developed a gel bead full of proteins that stick to the signalling molecules and deactivate them. As the molecules arrived at the centre of the embryonic chick face – around day 5 – Abzhanov added his bead to the mix. Sure enough, the chicks developed paired bones. "It looks exactly like a snout looks in an alligator [at this stage]," says Abzhanov, who presented his findings on 23 July at the Jackson Laboratory in Bar Harbor, Maine. Ethics regulations mean no such eggs can be hatched.

Long term Abzhanov, dreams of turning chickens back into Maniraptora, small dinosaurs thought to have given rise to the 10,000 species of birds around today. Others have similar musings. Palaeontologist Jack Horner described the basic principles in a book he co-wrote with James Gorman, *How to Build a Dinosaur* (Dutton Books, 2009), and regularly speaks of a future "chickenosaurus". "We are interested in finding a way to extend the tail and create a hand in the chicken," Horner told *New Scientist*, but would not elaborate.

The realisation that all it takes to create novel traits is a little genetic fine-tuning raises the possibility of engineering those shifts ourselves. Could we build the creatures of the future?

To a degree, we are already doing that, says Albertson. He and others are crossing closely related species – those that could conceivably pair on their own – and studying the resulting genetic changes. Sometimes those crosses result in novel creatures. For instance, Albertson crossed blue cichlid fish from neighbouring but separate populations and was surprised to find some of the offspring were red. He is trying to identify the genes and molecules involved, and says there is a possible advantage to the change. Some lakes that are home to cichlids are becoming increasingly murky, making it difficult for males to attract females with their colourful scales. Could it be that the bright red fish might have the edge, allowing the species to survive a more polluted world?

"Abzhanov dreams of turning chickens back into the dinosaurs they evolved from"

Amplifying the changes in the lab to create say, a fluorescent fish, may still be some way off, says Richard Schneider, of the University of California at San Francisco. So far, there are no ways to turn signalling pathways on; we can only rewind, not fast-forward evolution.

Understanding these subtleties could have a huge impact on medicine. Many developmental abnormalities – cleft palate for instance – arise from changes in gene signalling. Could we tweak them in a developing embryo? "I can envision a day when we eliminate such defects in the womb," says Jill Helms, a stem cell biologist at Stanford University in California. ■

QUCKS AND DUAILS

It's a perplexing fact that species as dissimilar as flies and humans share most of the same DNA. What could possibly trigger the huge differences in body structures?

The first real clue emerged in the late 1970s, when Edward Lewis and colleagues discovered genes in the fruit fly that are now known to control development in all animals. Specifically, Lewis found that genes in the "bithorax complex" give rise to flies' body segments. By tweaking them, Lewis grew a mutant fruit fly with an extra segment – giving them an extra pair of wings.

Since then, Richard Schneider and Jill Helms have crossed quails and ducks to isolate the genes responsible for developing the beak. When they transplanted the cells that give rise to beaks from one bird to the other, they swapped beaks. Quails grew wide bills and ducks grew pointy little quail beaks – the team had made qucks and duails. That suggested the cells were pre-programmed to build a specific beak and were simply following instructions in the host body.

This led to the realisation that key evolutionary stages may have happened when changes in existing genes switched on new pathways – a theory Scott Gilbert, an evolutionary developmental biologist at Swarthmore College in Pennsylvania, all but confirmed with his work in turtles. Gilbert showed that turtles had tapped into an ancient evolutionary pathway that directed the fgf10 molecule – which helps form limbs in other animals – to their skin. In effect, turtles flipped their ribcage inside out to produce a shell. "A small gene change," says Gilbert, "can give you birth defects or evolution."