Competition in Growth of Body Parts

By CAROL KAESUK YOON

The natural world is a study in proportions: giraffes with outrageously long necks, Tyrannosaurus rex with its tiny arms, and supermodels with legs that go on and on. But despite all the fun-house-mirror changes wrought by evolution, a lot of imaginable creatures have never existed.

Pondering the gaps in the endless spectrum of possibilities, some biologists have wondered whether it might be strictures of the developmental programs that build organisms — the rules that guide their growth from single cell to intricate adult — that could make building some kinds of creatures impossible.

A new study suggests that such architectural limitations may well be widespread. The study also suggests that these constraints may be caused by an entirely unexpected developmental phenomenon: competition among growing body parts.

Dr. Fred Nijhout, a developmental biologist at Duke University, and Dr. Douglas Emlen, an evolutionary biologist at the University of Montana, reported in a recent issue of Proceedings of the National Academy of Sciences that when dung beetles grew larger horns they invariably ended up with smaller eyes. Males that grew smaller horns had larger eyes. Studying butterflies, they found similar results looking at hind and fore wings.

They said the work suggested that body parts compete for resources, limiting each other's growth and final size, apparently preventing features from evolving to all imaginable proportions. It also makes some sorts of creatures — like big-horned, big-eyed dung beetles — highly unlikely, if not impossible, no matter how useful such a combination of traits might be.

"There's nothing in natural selection theory that says you can't have it all," Dr. David B. Wake, an evolutionary biologist at the University of California at Berkeley, said of the perceived power of natural selection to build organisms to ably meet all the demands of life. "But this paper convincingly demonstrates a constraint. We need to understand how evolution has maneuvered through this sea of constraints so as to understand what's going on."

In their study of the buckeye butterfly, Dr. Nijhout and Dr. Emlen removed from caterpillars a special group of cells, known as the imaginal disk cells, that would have eventually grown into the hind wing of the butterfly. When the adult butterfly emerged it had no hind wing, as expected, but it also had an enlarged fore wing, suggesting that one of the things holding back the growth of the fore wing was the presence of a nearby, growing hind wing.

"Darwin suggested long ago that there might be circumstances under which tissues are competing," Dr. Nijhout said. "We have the first evidence that there's more to growing an organ than just reading out some kind of genetic instructions, but that its final size is determined by an interaction between it and lots of other things in the body. That is really new."

The two researchers tested their ideas with dung beetles as well, selecting for big and small horned lines and using hormones to decrease horn size. They found the same thing. The bigger a beetle's horns, the smaller its eyes and vice versa.

Researchers say the apparent competition between body parts means that even though large horns are useful when males contest over females, beetles cannot evolve ever larger horns ad infinitum.

"The males might be superstuds, but they wouldn't be very good at seeing where they were going," said Dr. Emlen, who was a National Science Foundation postdoctoral researcher at Duke when the study was carried out.

Dr. Rudolf Raff, a developmental biologist at Indiana University in Bloomington, said there had been years of conjecture about the role that development might play, with people speculating enthusiastically about why there had never been six-legged brontosauruses or birds, like angels, with wings and arms as well.

"It's hard to really pin these things down," said Dr. Raff. "That's why what you really like to see are examples like this paper where you see some constraints."

In addition, the question of what regulates the evolution of huge, tiny or otherwise exaggerated traits has been the subject of speculation for more than 100 years.

Early on in the study of evolution, the explanations for fantastically proportioned creatures like Triceratops, with huge horns, or Tyrannosaurus, the gigantic meat eater, were that those races of creatures had gone senile. Every lineage, it was supposed, like every individual, started out young and rapidly growing, eventually becoming middle-aged and finally getting old, with some getting "senile" and losing the regulation of proper body forms.

No one would propose such theories today. Instead, a common explanation for how exaggerated traits like huge peacock tails and deer antlers evolved is that there was intense selection in mating that favored males with the showiest, largest features. What kept males from evolving ever bigger ornaments, researchers assumed, was the problem of how to find food and escape from predators bearing such a burden.

The new study suggests instead that the reason these male ornaments do not evolve to even more ridiculous proportions is that if they do, another perhaps equally crucial structure will be diminished.

"How much to put into advertisement and how much to put into growth of the body and the sensory structures?" said Dr. Gerald Wilkinson, an evolutionary biologist at the University of Maryland who works on bizarre-looking flies in which the males have huge eye stalks.

This unconventional push me-pull me picture of animals with conflicts between the growing body parts is an uncomfortable one for developmental biologists. For years, researchers have been accumulating evidence that body parts, despite their surroundings, grow to their proper genetically determined sizes. When the beginnings of a leg or wing are transplanted to the abdomen of a fly, that leg or wing will grow to its proper proportions and no larger.

These researchers say the study raises many more questions than it answers. For while this view of development looks superficially like a zero-sum game of resources where what one body part gets, the others lose, the interaction between body parts may be more complex than that. The authors conceded that there were nearly limitless possibilities for how body parts might influence each other's growth. Different parts could alter their sizes by changing how they compete for nutrients, but also by changing their timing or rate of growth, how they compete for factors like hormones, and so on.

Dr. William R. Atchley, an evolutionary biologist at North Carolina State University in Raleigh, went even further saying, "I'm sure there's competition among body parts in humans."

So does the new work suggest that Ross Perot's ears were grown at the cost of another structure in his head or that Cindy Crawford's inordinately long legs mean she was shorted elsewhere?

Researchers declined to comment on anyone's body parts in particular. Instead, they noted that while there was no evidence that any of the more intriguing proportional anomalies in humans was caused by competition among body parts, such competition and all its effects remain possible, at least theoretically, in humans.