

READING #1 ON CONTRIVANCES: The Panda's Thumb

Excerpted from "The Panda's Thumb" out of *The Panda's Thumb: More Reflections in Natural History* by Stephen Jay Gould, W.W Norton & Company, New York, 1980.

"Our textbooks like to illustrate evolution with examples of optimal design—nearly perfect mimicry of a dead leaf by a butterfly or of a poisonous species by a [tasty] relative. But ideal design is a lousy argument for evolution.... Odd arrangements and funny solutions are the proof of evolution—paths that a sensible God would never tread but that a natural process, constrained by history, follows perforce.... Which brings me to the giant panda and its "thumb."

"Giant pandas are peculiar bears, members of the order Carnivora. Conventional bears are the most omnivorous representatives of their order, but pandas subsist... almost entirely on bamboo. They live in dense forests of bamboo at high elevations in the mountains of western China. There they sit, largely unthreatened by predators, munching bamboo ten to twelve hours each day.

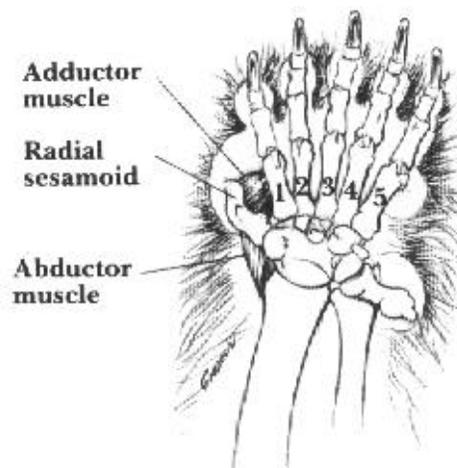
"As a childhood fan of Andy Panda, and former owner of a stuffed [panda] toy won by some fluke when all the milk bottles actually tumbled at the county fair, I was delighted when the first fruits of our thaw with China went beyond ping pong to the shipment of two pandas to the Washington Zoo. I went and watched in appropriate awe. They yawned, stretched, and ambled a bit, but they spent nearly all their time feeding on their beloved bamboo. They sat upright and manipulated the stalks with their forepaws, shedding the leaves and consuming only the shoots.

"I was amazed by their dexterity and wondered how the [heir] of a [lineage] adapted for running could use its hands so adroitly. They held the stalks of bamboo in their paws and stripped off the leaves by passing the stalks between an apparently flexible thumb and the remaining fingers. This puzzled me. I had learned that a dexterous, opposable thumb stood among the hallmarks of human success. We had maintained, even exaggerated, this important flexibility of our primate forebears, while most mammals had sacrificed it in specializing their digits. Carnivores run, stab, and scratch. My cat may manipulate me psychologically, but he'll never type or play the piano.

"So I counted the panda's other digits and received an even greater surprise: there were five, not four. Was the "thumb" a separately evolved sixth finger?... D. Dwight Davis,...of... Chicago's Field Museum of Natural History...had the answer....

"The panda's "thumb" is not, anatomically, a finger at all. It is constructed from a bone called the radial sesamoid, normally a small component of the wrist. In pandas, the radial sesamoid is greatly enlarged and elongated until it almost equals [the length of the first bones of the true fingers. It] underlies a pad on the panda's forepaw; the five digits form the framework of another pad.... A shallow furrow separates the two pads and serves as a channelway for bamboo stalks.

"The panda's thumb comes equipped not only with a bone to give it strength but also with muscles to sustain its agility." [This adaptation did not arise by magic, but from parts of the organism already in place. The panda's opposable sixth digit arose from a wrist bone already enlarged and supported by musculature found in all bears and raccoons, the panda's closest relatives.] "The panda's true thumb is committed to another role, too specialized for a different function to become an opposable, manipulating digit. So the panda must use parts on hand and settle for an enlarged wrist bone and a somewhat clumsy, but quite workable, solution."



D.L. CRAMER

READING #2 ON CONTRIVANCES: Orchids

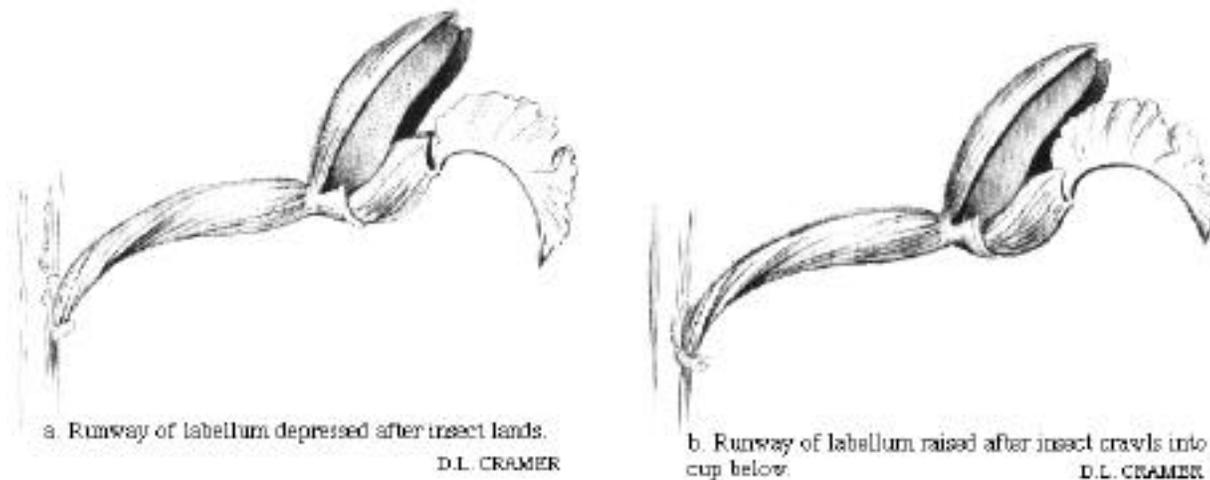
Excerpted from "The Panda's Thumb" out of *The Panda's Thumb: More Reflections in Natural History* by Stephen Jay Gould, W.W Norton & Company, New York, 1980.

"Darwin's orchid book* is filled with similar illustrations [of unique adaptations].... Orchids have formed an alliance with insects. They have evolved an astonishing variety of "contrivances" to attract [visitors], guarantee that sticky pollen adheres to their visitor, and ensure that the attached pollen comes in contact with female parts of the next orchid visited by the insect.... Orchids manufacture their intricate devices from the common components of ordinary flowers, parts usually fitted for very different functions.... Orchids were not made by an ideal engineer; they are jury-rigged from a limited set of available components. Thus, they must have evolved from ordinary flowers.

"The marsh *Epipactis*, for example, uses its labellum—an enlarged petal—as a trap. The labellum is divided into two parts. One, near the flower's base, forms a large cup filled with nectar—the object of an insect's visit. The other, near the flower's edge, forms a sort of landing stage. An insect alighting on this runway depresses it and thus gains entrance to the nectar cup beyond. It enters the cup, but the runway is so elastic that it instantly springs up, trapping the insect within the nectar cup. The insect must then back out through the only available exit—a path that forces it to brush against the pollen masses. A remarkable machine but all developed from a conventional petal, a part readily available in an orchid's ancestor.

"Darwin then shows how the same labellum in other orchids evolves into a series of ingenious devices to ensure cross-fertilization. It may develop a complex fold that forces an insect to detour its proboscis around and past the pollen masses in order to reach nectar. It may contain deep channels or guiding ridges that lead insects both to nectar and pollen. The channels sometimes form a tunnel, producing a tubular flower. All these adaptations have been built from a part that began as a conventional petal in some ancestral form. Yet nature can do so much with so little that it displays, in Darwin's words, "a prodigality of resources for gaining the very same end, namely, the fertilization of one flower by pollen from another plant."

Marsh *Epipactis*, lower sepals removed



**On the Various Contrivances by Which British and Foreign Orchids Are Fertilized by Insects* by Charles Darwin (1862).

READING #3 ON CONTRIVANCES: Preadaptations

Excerpted from "The Problem of Perfection, or How Can a Clam Mount a Fish on Its Rear End?", in *Ever Since Darwin: Reflections in Natural History*, by Stephen Jay Gould, W.W Norton & Co., New York, 1977.

A problem with adaptation as a major agent of evolution is that there are organs (let alone organisms) that seem just too complex, too beautifully adapted, to have formed in the seemingly random manner of natural selection. And if the organ was developed in many tiny incremental steps, what on earth was the use of being only part way there?

That is the key to the concept of preadaptation - each of those incremental steps must have been useful. And we shouldn't lock ourselves into its being useful in the same way it is useful now, but to keep open to the idea that it just needed to be functional *somehow*.

"Preadaptation" is a tricky term. It sounds like it pops back to Lamarckian ideas - like preregistration for college when you sign up in advance for what you think you'll be needing to take next term. Actually, a preadaptation is just the opposite. It's a trait already there in the organism available to be made useful in a new way. Like the unusual wrist bone and accompanying musculature in bears and raccoons that we see has evolved in the panda to its bamboo-manipulating extra thumb. Stephen Jay Gould has an intriguing example in *Ever Since Darwin*:

"Every naturalist has his favorite example of an awe-inspiring adaptation. Mine is the "fish" found in several species of the freshwater mussel *Lampsilis*. Like most clams, *Lampsilis* lives partly buried in bottom sediments, with its posterior end protruding. Riding atop the protruding end is a structure that looks for all the world like a little fish. It has a streamlined body, well-designed side flaps complete with a tail and even an eyespot. And, believe it or not, the flaps undulate with a rhythmic motion that imitates swimming." What is this little "fish"?

"Most clams release their eggs directly into the surrounding water, where they are fertilized and undergo their embryonic development. But female ... freshwater mussels retain their eggs within their bodies, where they are fertilized by sperm released into the water by nearby males. The fertilized eggs develop in tubes within the gills, forming a brood pouch.

"In [these mussels], the inflated [brood pouch]... forms the "body" of its [so-called] fish. Surrounding the fish, symmetrically on both sides, are extensions of the mantle, the "skin" that encloses the soft parts of all clams and usually ends at the shell margin. These extensions are elaborately shaped and colored to resemble a fish, with a definite, often flaring "tail" at one end and an "eyespot" at the other. A special [set of nerves] located inside the mantle edge innervates these flaps. As the flaps move rhythmically, a pulse, beginning at the tail, moves slowly forward to propel a bulge in the flaps along the entire body. This intricate apparatus, formed by the [pouch] and mantle flaps, not only looks like a fish but also moves like one.

Why would this have evolved? There may be an answer in the bizarre reproductive biology of our mussel. "The larvae of [freshwater clams] cannot develop without a free ride upon fishes during their early growth. ... In order to survive, [they] must enter a fish's mouth and move to favored sites on the gills. The [fake] "fish" of *Lampsilis* is an animated decoy, simulating both the form and movement of the animal it must attract. When a fish approaches, [the mussel] discharges larvae from the [pouch]; some of them will be swallowed by the fish and find their way to its gills."

Now the big question: how did our mussel get its fishlike fish-lure?

"*Ligumia nasuta*, a "cousin" of *Lampsilis*, [offers a possible intermediate form of our mussel's fishy adaptation.] Females of this species do not have mantle flaps, but they do possess darkly pigmented, ribbon-like membranes that bridge the gap between partly opened shells....Through this gap, the white color of the interior soft parts stands out against the dark pigment of the ribbon." Waves along the dark membrane occur frequently, as often as every two seconds, making the white spot of color from the interior of the mussel appear "to move toward the back of the shell. J.H. Welsh wrote in the May 1969 issue of *Natural History*:

"The regularity of the rhythm is remarkably constant. To a human observer, and perhaps to a fish, the eye-catching feature here is the white spot that appears to move against the dark background of the

mussel and the substrate in which it is half buried. Certainly this could be a lure to host fish and may represent a specialized adaptation from which the more elaborate, fishlike lure evolved.

“We are still dealing with a device to attract fish, but the mechanism is abstract, regular motion, not visual mimicry.... Motion of the mantle attracted fish from the start; the slow development of an "alternate technology" only enhanced the process.”

Our freshwater mussel itself answers another question. L.R. Kraemer is a leading student of *Lampsilis*... “She believes that [the fish] flapping may have evolved either to aerate the larvae within the [pouch] or to keep them suspended in the water after their release. Again, if flapping provided these other advantages from the start, then the [fortunate] resemblance of flaps to fish might be a **preadaptation**. The initial, **imperfect** mimicry could be improved by natural selection while the flaps performed other important functions.”

Name _____

Date _____ Per. _____

READINGS ON CONTRIVANCES
Questions for Reading and Discussion

Read the first two essays (on the panda's thumb, and on orchids), and answer questions 1&2. Then read over questions 3 & 4, and be prepared to discuss them in a small group in class tomorrow.

1. What is the panda's thumb? What is its origin?

 2. An important evolutionary concept is that self-fertilization will not work well for long-term survival. Offspring carry only the genes of one parent, which will not give them enough variation to make them flexible "in the face of environmental change. As a result, plants bearing flowers with both male and female parts usually evolve mechanisms to ensure cross-pollination."
 - a) How do organisms achieve variation?

 - b) How is variation specially ensured by the orchids?

 3. Put into you own words the idea put forth by Gould (with Darwin's help) in the last sentence of the orchid essay.

 4. What is a contrivance? (your definition, and an example):

 5. "Nature is", in biologist Francois Jacob's words, "an excellent tinkerer, not a divine artificer." Using the panda's thumb and the contrivances of orchids as your support, explain Gould's point in this quote. (This may be assigned as a short essay for homework).
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- OPTIONAL If provided: read contrivance reading #3: "Preadaptations", and answer these questions:
6. Define in your own words "preadaptation".

 7. What actually makes up the mussel's "fish"?

 8. What did Gould mean in the second to last paragraph by "alternate technology"?

 9. What adaptations that are not mimicry might explain the undulation of the mantle flaps in *Lampsilis*?

 10. How on earth could it be that the mussel's "fish-lure" evolved?