February 10, 2009

Genes Offer New Clues in Old Debate on Species' Origins

By CAROL KAESUK YOON

Charles Darwin called it the "mystery of mysteries," a problem so significant and one he was so sure he had solved that he named his world-changing work after it: "On the Origin of Species." So he might be surprised to learn that 150 years after the publication of his book, the study of how species originate, a process known as speciation, is not only one of the field's most active areas of study, but also one of its most contentious.

While researchers agree that many of the recent breakthroughs would have come as a huge surprise to the grand old man, they seem to disagree about almost everything else, from what a species is to what exactly is meant by the origin of species and even whether Darwin shed any light on the process at all.

"Speciation is definitely one of the big-picture grand themes of evolutionary biology," said Mary Jane West-Eberhard, an evolutionary biologist at the Smithsonian Tropical Research Institute in Panama. She described study of the process as "an apparent turmoil that might be misunderstood by an outsider as a caldron of doubts and uncertainties but that in fact is a vitally alive science."

Part of the difficulty with studying the origin of species comes from the vastness of the question — how did the diversity of all life on Earth arise, from orchids to elephants to bacteria to ourselves? It is difficult, too, to try to reconstruct events — the birth of species — long past.

"A decade ago, the joke was that spell-checkers regularly attempted to substitute the word 'speciation' with 'speculation,'" Mohamed Noor, an evolutionary biologist at Duke University, wrote in a commentary in the journal Nature. But he added, "Speculation in this area will soon be a thing of the past."

To support such optimism, researchers point to the recent discovery of so-called speciation genes. Most biologists define a species as a group that is reproductively isolated — it cannot interbreed or exchange genes with any other. The newly discovered genes cause reproductive isolation between two groups by causing their offspring, or hybrids, to be infertile or die. Scientists say the identities of the long-sought genes, several of which have recently been pinpointed in fruit flies, mice, fish and yeast, came as a surprise.

On Friday, Daven Presgraves, an evolutionary biologist at the University of Rochester, and colleagues published a paper in the journal Science identifying the latest such gene to be discovered. It is the second one that the team has found in fruit flies. The newly discovered gene, Nup 160, like its predecessor, Nup 96, causes reproductive isolation between the species Drosophila melanogaster and Drosophila simulans.

Unexpectedly, the genes both produce proteins that are part of a large piece of cellular machinery known as the nuclear pore complex, a gateway that controls what molecules move into and out of the nucleus. It is still

unclear why, in what Dr. Presgraves describes as a blind search for genes that cause problems in hybrids, his team twice pulled out genes involved in the nuclear pore complex or why the complex might be particularly important in the evolution of reproductive isolation.

“The question is,” said Douglas Futuyma, an evolutionary biologist at the State University of New York at Stony Brook, “what the hell does this have to do with hybrid sterility?”

One reason some scientists object to the use of the term “speciation genes” is that although the genes cause reproductive isolation, it is not clear whether the genes in question caused the initial reproductive isolation responsible for the origin of the species.

To get closer to the crucial early stages of reproductive isolation, Kirsten Bomblies, an evolutionary biologist at the Max Planck Institute for Developmental Biology in Tübingen, Germany, and colleagues study hybrids that are the offspring of crosses between strains of plants within a single species. Surprisingly, even among different strains of the weed Arabidopsis thaliana, Dr. Bomblies said, “some crosses fail catastrophically.” The hybrids are “tiny, their leaves are twisted and warped, they have massive die-off of cells, and the worst cases are unable to flower.”

As with the Drosophila genes, the function of the hybrid-disrupting genes found in Arabidopsis has come as a surprise. They appear to be genes for disease resistance, suggesting that the rapid evolution of disease resistance in different strains may be the beginning of the evolution of reproductive isolation between them. The study may have significance far beyond Arabidopsis; Dr. Bomblies, who last year won a MacArthur Foundation fellowship for her research, notes that breeders have noticed the withering of different strains’ offspring in a variety of species, including wheat, tobacco, cotton and the houseplant Streptocarpus.

Loren Rieseberg, an evolutionary biologist at the University of British Columbia who was not involved with the study, said the work was important because it suggested that an entire class of genes, those involved with fending off disease, and a particular kind of natural selection — that imposed by disease organisms — could be broadly important in speciation in plants. (Read comments by Dr. Rieseberg's on "On the Origin of Species.")

The surprises now being found in the DNA of diverging species are, of course, things Darwin could never have guessed at. Having written “Origin of Species” decades before Gregor Mendel’s genetic work was rediscovered, he certainly did not anticipate such findings in his vision of the diversification of life.

“Genetics was one area where he really fell down,” said Jerry Coyne, an evolutionary biologist at the University of Chicago and the author of “Why Evolution Is True” (Penguin, 2009).

Yet the strongest pattern emerging from the study of these speciation genes is one Darwin might well have expected. The single widespread commonality is that nearly all appear to have diverged to produce reproductive isolation as a result of adaptation under powerful natural selection.

More than anything else, Darwin focused on adaptation via natural selection in the shaping of the diversity of life. The finding comes as something of a surprise to modern biologists, however, because in the absence of evidence, it was plausible that random divergence over time might also have been an important force

leading groups to becoming distinct species.

“Probably the most important finding,” Dr. Rieseberg said, “is that selection is driving the process.”

The harking back to Darwin’s emphasis on selection goes well beyond studies of DNA. A particularly powerful type of selection that Darwin emphasized was sexual selection, as when females choose showy mates and male suitors violently combat one another, which can lead to the evolution of things like peacock tails or massive deer antlers.

Now new studies are providing increasing evidence that sexual selection is capable not only of producing outrageous structures but also new species, an idea of Darwin’s that Dr. West-Eberhard describes as “almost completely forgotten for nearly a century.”

A small Amazonian frog known as Physalaemus petersi provides a particularly strong example of how females’ choosiness in mates may be driving the formation of a new species. Males of the mottled brown species reach just over an inch in length and can be found singing in choruses to attract females. In some populations, the males’ song is what is called a “whine” — a kind of frog meow. But in other populations, males whine and add a squawk. Michael J. Ryan, an evolutionary biologist at the University of Texas, Austin, and colleagues have found that the difference evolved because females in one population preferred pure whine, whereas in another they preferred whine and squawk.

What is particularly interesting about petersi, though, is that the female frogs’ preference for different songs in different populations also appears to be causing the populations to begin to evolve into distinct species. When given a choice of songs from either population, females nearly uniformly prefer their own population’s song, as strictly as if the two populations belonged to two long separated species. The researchers have even gathered evidence that the populations that prefer different songs, while very closely related, appear to be beginning to diverge from one another genetically, suggesting they are moving down the path toward becoming separate species.

So if Darwin pointed out the importance of selection, and even the power of sexual selection, why the often heard claim that the “Origin” has little to say about how species originate?

The problem lies in how biologists define a species. Today, the most common definition of a species is a group that is reproductively isolated from other groups, the biological species concept set out by the evolutionary biologist Ernst Mayr in 1942. As a result, the origin of species is, necessarily, considered the origin of reproduction isolation. Yet both concepts would have been rather foreign to Darwin.

Darwin, who once wrote that species were “indefinable,” might have described a species as a segment of a branch on the ever-expanding tree of life, the same tree he drew as the only figure in the “Origin.” Or he might have said it was something more distinct than a variety and less than a genus.

And there are some biologists today who say that Darwin in all his vagueness, not modern biologists, had the definition right. David Wake, an evolutionary biologist at the University of California, Berkeley, has studied Ensatina salamanders for decades. He says their patterns of interbreeding and adaptation simply do not yield to their being divided into species as dictated by the biological species concept.

His salamanders, he said, like so many other real living things, are “much messier” than a definition like the biological species concept allows. Consider asexual species. If a species is an entity that does not exchange genes with others, then every asexual organism, every individual bacterium, for example, could be considered a separate species, hardly a useful distinction. And the complications go on and on.

So perhaps Darwin hit the mark, at least the mark he intended, when he chose his famed title.

“I think he’s not referring to how do you get two species of finch out of one,” Dr. Futuyma said of “Origin of Species.” “I think what he means is something much more embracing, something we would today call the origin of biological diversity. You could be talking about two species of finches or a human versus a giraffe or an oak tree for that matter. The world is full of species, and his book clearly embraces the whole thing.”

Darwin’s own last words in the book suggest just such a broad scope: “There is grandeur in this view of life,” he wrote, that “from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.”