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New insight into primate eye evolution

May 18 2009

Researchers comparing the fetal development of the eye of the owl monkey with that of the capuchin monkey have found that only a minor difference in the timing of cell proliferation can explain the multiple anatomical differences in the two kinds of eyes.

The findings help scientists understand how a structure as complex as the eye could change gradually through evolution, yet remain functional. The findings also offer a lesson in how seemingly simple genetic changes in the brain and nervous system could produce the multiple evolutionary changes seen in more advanced brains, without compromising function.

Analysis for this study was performed at St. Jude Children's Research Hospital. The primates were housed at the Centro Nacional de Primates in Brazil. Contributing researchers at Cornell University and Universidade Federal do Pará, Brazil, approved all procedures. The researchers published their findings in the early online issue of *Proceedings of the National Academy of Sciences*.

"The molecular, cellular and genetic pathways that coordinate proliferation during development have been fine-tuned since the first multicellular organisms emerged millions of years ago," said Michael Dyer, Ph.D., member of St. Jude Developmental Neurobiology and the paper's first author. "When these pathways are deregulated during human development, one of the consequences is childhood cancer. Therefore, by studying how changes in the regulation of proliferation during development can lead to dramatic changes in form and function during evolution, we can gain a deeper understanding of these ancient pathways that lie at the heart of many pediatric cancers."

The owl monkey's eye has numerous adaptations to make it effective for nocturnal (active during the night) function. For example, it has a greater number of rod photoreceptor cells than the capuchin monkey, which is diurnal (active during the day). Rod cells are the most light-sensitive cells in the retina making them effective for nighttime vision. The owl monkey's nocturnal retina is also larger and lacks a fovea, the central region of high-density cone photoreceptors that gives the diurnal eye high acuity and daytime color vision.

For both owl and capuchin monkeys, the specialized cell types in the eye all develop in the growing embryo from a single type of immature cell, called a retinal progenitor cell.

"These two species evolved about 15 million years ago from a common ancestor that had a diurnal eye," Dyer said. "So, we believe that comparing how their eyes develop during embryonic growth could help us understand what evolutionary changes would be required to evolve from a diurnal to a nocturnal eye."

The researchers hypothesized that only speeding up or slowing down the proliferation of the progenitor cells in the developing embryo might actually change the types of cells that they became. Thus, the evolutionary adaptation from diurnal to nocturnal eye might require no more than a modest genetic change that affected that timing.

Such a concept—that timing of cell proliferation might profoundly affect anatomy—has broader implications for understanding how the complex human brain evolved from simpler mammalian brains, Dyer said. In earlier comparative studies of the brains of more than 100 mammalian species, the study's first author, Barbara Finlay, Ph.D., of Cornell University, Ithaca, New York, had found that those parts of the brain that are disproportionately larger in more complex brains develop last during embryonic growth.

"This finding suggested that changes in the growth of the brain during embryonic development could be a mechanism for evolutionary change," Dyer said. "In other words, maybe the parts of the human brain that are bigger than in other mammals are bigger simply because the period of their growth is extended during fetal development."

In their analysis, Dyer and his colleagues compared the timing of retinal progenitor cell proliferation into the different types of mature retinal cells in owl and capuchin monkey embryos. They found evidence that the extended period of progenitor cell proliferation in the owl monkey eye did, indeed, give rise to the different population of retinal cells that made the eye specially adapted for nocturnal vision.

They also found evidence that this extended period of proliferation also caused the size of the eye to be larger, which is necessary for the eye to accommodate the larger light-gathering and light-sensing structures necessary for nocturnal vision.

"The beauty of the evolutionary mechanism we have identified is that it enables the eye to almost toggle back and forth between a nocturnal and a diurnal structure," Dyer said. "It is an elegant system that gives the eye a lot of flexibility in terms of specialization."

More broadly, Dyer said, the finding offers support for the idea that important changes in brain structure can evolve via simple genetic changes that affect the timing of development of brain regions.

Source: St. Jude Children's Research Hospital