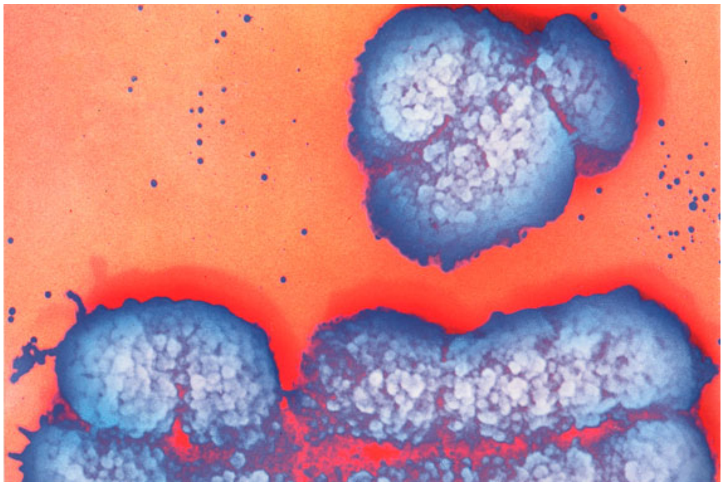
Whitehead Institute

THEORY OF THE "ROTTING" Y CHROMOSOME DEALT A FATAL BLOW



Although the human Y chromosome (top) intially lost so much genetic material that it is dwarfed by X chromosome (bottom), Whitehead Member David Page's lab has revealed that there has been remarkable genetic stability on the rhesus macaque and human Ys in the years since their evolutionary split 25 million years ago. This indicates that the human Y chromosome has a long, healthy future ahead of it.

Image: Courtesy of Howard Hughes Medical Institute (HHMI)

FEBRUARY 22, 2012

TAGS: PAGE LAB EVOLUTION + DEVELOPMENT GENETICS + GENOMICS

CAMBRIDGE, Mass. – If you were to discover that a fundamental component of human biology has survived virtually intact for the past 25 million years, you'd be quite confident in saying that it is here to stay.

Such is the case for a team of Whitehead Institute scientists, whose latest research on the evolution of the human Y chromosome confirms that the Y—despite arguments to the contrary—has a long, healthy future ahead of it.

Proponents of the so-called rotting Y theory have been predicting the eventual extinction of the Y chromosome since it was first discovered that the Y has lost hundreds of genes over the past 300 million years. The rotting Y theorists have assumed this trend is ongoing, concluding that inevitably, the Y will one day be utterly devoid of its genetic content.

Over the past decade, Whitehead Institute Director David Page and his lab have steadily been churning out research that should have permanently debunked the rotting Y theory, but to no avail.

"For the past 10 years, the one dominant storyline in public discourse about the Y is that it is disappearing," says Page. "Putting aside the question of whether this ever had a sound scientific basis, the story went viral—fast—and has stayed viral. I can't give a talk without being asked about the disappearing Y. This idea has been so pervasive that it has kept us from moving on to address the really important questions about the Y."

To Page, this latest research represents checkmate in the chess match he's been drawn into against the "rotting Y" theorists. Members of his lab have dealt their fatal blow by sequencing the Y chromosome of the rhesus macaque—an Old World monkey whose evolutionary path diverged from that of humans some 25 million years ago—and comparing it with the sequences of the human and chimpanzee Y chromosomes. The comparison, published this week in the online edition of the journal Nature, reveals remarkable genetic stability on the rhesus and human Ys in the years since their evolutionary split.

Grasping the full impact of this finding requires a bit of historical context. Before they became specialized sex chromosomes, the X and Y were once an ordinary, identical pair of autosomes like the other 22 pairs of chromosomes humans carry. To maintain genetic diversity and eliminate potentially harmful mutations, autosome pairs swap genes with each other in a process referred to as "crossing over." Roughly 300 million years ago, a segment of the X stopped crossing over with the Y, causing rapid genetic decay on the Y. Over the next hundreds of millions of years, four more segments, or strata, of the X ceased crossing over with the Y. The resulting gene loss on the Y was so extensive that today, the human Y retains only 19 of the more than 600 genes it once shared with its ancestral autosomal partner.

"The Y was in free fall early on, and genes were lost at an incredibly rapid rate," says Page. "But then it leveled off, and it's been doing just fine since."

How fine? Well, the sequence of the rhesus Y, which was completed with the help of collaborators at the sequencing centers at Washington University School of Medicine and Baylor College of Medicine, shows the chromosome hasn't lost a single ancestral gene in the past 25 million years. By comparison, the human Y has lost just one ancestral gene in that period, and that loss occurred in a segment that comprises just 3% of the entire chromosome. The finding allows researchers to describe the Y's evolution as one marked by periods of swift decay followed by strict conservation.

"We've been carefully developing this clearcut way of demystifying the evolution of the Y chromosome," says Page lab researcher Jennifer Hughes, whose earlier work comparing the human and chimpanzee Ys revealed a stable human Y for at least six million years. "Now our empirical data fly in the face of the other theories out there. With no loss of genes on the rhesus Y and one gene lost on the human Y, it's clear the Y isn't going anywhere."

"This paper simply destroys the idea of the disappearing Y chromosome," adds Page. "I challenge anyone to argue when confronted with this data."

This work was supported by the National Institutes of Health, the Howard Hughes Medical Institute, and the Charles A. King Trust.

Written by Matt Fearer

* * *

David Page's primary affiliation is with Whitehead Institute for Biomedical Research, where his laboratory is located and all his research is conducted. He is also a Howard Hughes Medical Institute investigator and a professor of biology at Massachusetts Institute of Technology.

* * *

Full Citation:

"Strict evolutionary conservation followed rapid gene loss on human and rhesus Y chromosomes"

Nature, online February 22, 2012

Jennifer F. Hughes (1), Helen Skaletsky (1), Laura G. Brown (1), Tatyana Pyntikova (1), Tina Graves (2), Robert S. Fulton (2), Shannon Dugan (3), Yan Ding (3), Christian J. Buhay (3), Colin Kremitzki (2), Qiaoyan Wang (3), Hua Shen (3), Michael Holder (3), Donna Villasana (3), Lynne V. Nazareth (3), Andrew Cree (3), Laura Courtney (2), Joelle Veizer (2), Holland Kotkiewicz (2), Ting-Jan Cho (1), Natalia Koutseva (1), Steve Rozen (1), Donna M. Muzny (3), Wesley C. Warren (2), Richard A. Gibbs (3), Richard K. Wilson (2), David C. Page (1).

1. Howard Hughes Medical Institute, Whitehead Institute, and Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

2. The Genome Institute, Washington University School of Medicine, St. Louis, Missouri, USA.

3. Human Genome Sequencing Center, Baylor College of Medicine, Houston, Texas, USA.

Whitehead Institute for Biomedical Research is a nonprofit, independent research and educational institution. Wholly independent in its governance, finances and research programs, Whitehead shares a close affiliation with Massachusetts Institute of Technology through its faculty, who hold joint MIT appointments.