Researchers Present New Sex Evolution Theory

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(PhysOrg.com) -- Harris Bernstein and Carol Bernstein have proposed a new theory on the billion-year-old mystery of sexual reproduction evolution.

The origin of the evolutionary game - the ability of animals (including humans) and plants to reproduce sexually, genetically recombine to repair DNA, and then produce eggs, sperm or pollen - is an unresolved mystery in biology.

In an article published in the July/August issue of BioScience, University of Arizona researchers Harris Bernstein and Carol Bernstein provide insights into the early evolution of sexual organisms and the role environmental stressors had on sexual reproduction as a key survival strategy.

The UA department of cell biology and anatomy researchers argue that eukaryotes, or cells with a nucleus, adapted their meiotic ability to recombine chromosomes sexually into new genetically distinct entities from their ancestors, called prokaryotic cells.

The ability to recombine chromosomes through meiosis gives rise to eggs and sperm in humans. According to the Bernsteins' theory, meiosis evolved to promote DNA repair, thereby greatly reducing DNA damage in resulting eggs and sperm.

After the repair during meiosis, when an egg meets a sperm, the chance of having a viable fetus is much improved, and the chance that the baby will have a newly arisen genetic defect is reduced.

Prokaryotic cells evolved to develop the ability to repair DNA through a process called transformation, which also promotes chromosome repair through a process called recombination.

In prokaryotic cells (which include bacteria), asexual reproduction is completed through a process called binary fission. In binary fission, each strand of the original double-stranded DNA molecule serves as template for the reproduction of a complementary strand as the cell readies to split into two parts.

Under certain conditions, these cells are capable of the exchange and repair of DNA through a process called transformation. Transformation is the transfer of a fragment of DNA from a donor cell to a recipient

cell, followed by recombination in the recipient chromosome. The researchers call this bacterial process an early version of sex.

For eukaryotes, which include higher animals and plants as well as single-celled species such as yeast, reproduction occurs in two ways, through mitosis or meiosis.

In mitosis, one cell divides to produce two genetically identical cells. In cells committed to mitosis, if there is DNA damage, a good deal of the damage can be repaired, especially the damage on one strand of the DNA, where information on the opposite strand can direct the repair on the damaged strand of the double helical DNA.

Meiosis is required in sexual reproduction in eukaryotes. During meiosis, a cell with two copies of each chromosome, one from each parent, undergoes the process of recombination. This allows a special type of repair, not available during ordinary mitosis.

During meiotic recombination, the pairs of chromosomes line up next to each other, and if there is damage on either chromosome, repair can take place by recombination with the other chromosome. Meiotic recombination allows for the repair of damaged DNA as the chromosomes from each parent are broken and joined, resulting in different combinations of genes in each chromosome.

The prevailing theory is that eukaryotes developed the ability for meiosis and sexual reproduction from their ability to reproduce through mitosis and not from their early ancestor's ability to reproduce through transformation.

"Our proposal, that the sexual process of meiosis in eukaryotes arose from the sexual process of transformation in their bacterial ancestors, is a new and fundamentally different perspective that will likely generate

controversy," the researchers predict.

Harris Bernstein is a professor of cell biology and anatomy. Carol Bernstein is an associate research professor of cell biology and anatomy.

"If it is assumed that meiosis arose only after mitosis was established, there would have been an extended period (while mitosis was evolving) when there was no meiosis, and therefore no sex, in eukaryotes. This assumption appears to be contradicted by evidence that the basic machinery for meiosis was present very early in eukaryote evolution," the authors state.

A key argument in their hypothesis is that in both prokaryotes and simple eukaryotes, sexual cycles are induced by stressful conditions. Thus, the recombinational repair promoted by transformation and meiosis is part of a survival strategy in response to stress.

"Coping with DNA damage appears to be a fundamental problem for all life. For instance, the average human cell incurs about 10,000 DNA damages per day, of which 50 are double-strand breaks. The DNA damages are mostly due to the reactive oxygen species generated when converting food into energy. Thus, efficient DNA recombinational repair is an adaptation for cell survival and for producing new offspring, in higher organisms, through meiosis," the researchers contend.

In bacteria - the most common prokaryote - transformation is typically induced by high cell density, nutritional limitation, or DNA-damaging conditions. In yeast, a eukaryote or protist, the meiotic sexual cycle is induced when the supply of nutrients becomes limiting or when the cells are exposed to oxidative stress and DNA damage, the team added.

"Observations suggest that facultative sex in bacteria and protists is often an adaptive response to stressful environmental conditions, as would be

expected if transformation and meiosis were related adaptations," the researchers write.

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