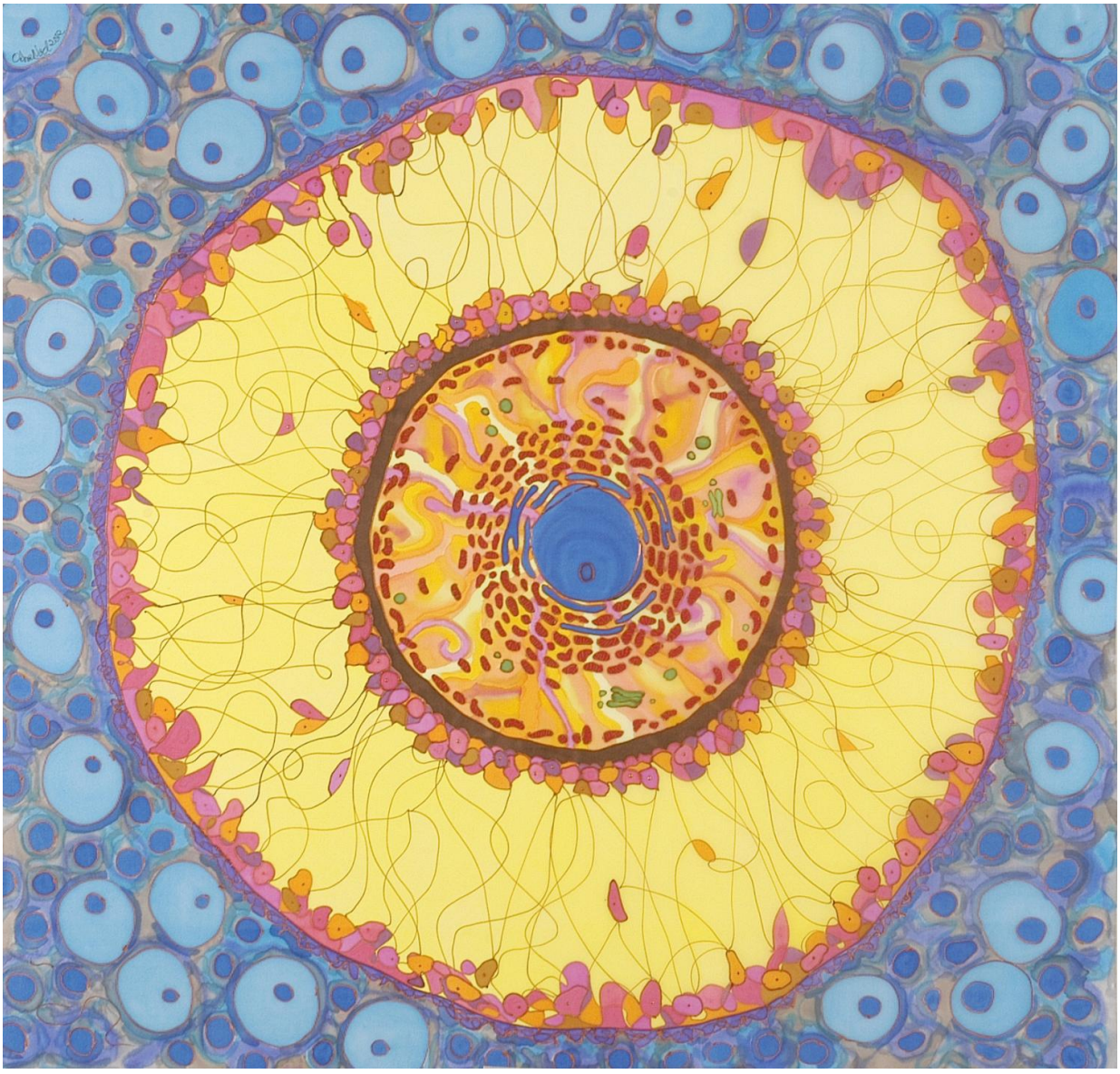
Sex cells evolved to pass on quality mitochondria

December 20 2016



One of a series of ova made in a spell of reproductive mitochondrial interest.

The ovum about to ovulate has differentiated from the rest of the surrounding tissue and is getting ready to leave the ovary. Its mitochondria are organized mainly around the nucleus. The cell is full of potential and force. A big journey of life may be about to start. Credit: Odra Noel

Mammals immortalise their genes through eggs and sperm to ensure future generations inherit good quality mitochondria to power the body's cells, according to new UCL research.

Before now, it was not known why mammals rely on dedicated sex cells that are formed early in development (a germline) to make offspring whereas plants and other simple animals, such as corals and sponges, use sex cells produced later in life from normal body tissues.

In a new study, published today in *PLOS Biology* and funded by Natural Environment Research Council, Engineering & Physical Sciences Research Council and the Leverhulme Trust, UCL scientists developed an evolutionary model to investigate how these differences evolved over time and discovered that the germline in mammals developed in response to selection on mitochondria (the powerhouses of cells).

First author and UCL PhD student, Arunas Radzvilavicius, said: "There have been many theories about why mammals have a specialised germline when plants and other ancient animals don't. Some suggest it was due to complexity of tissues or a selfish conflict between cells. The distinction between sex cells and normal body tissues seems to be necessary for the evolution of very complex specialised tissues like brain.

"Surprisingly, we found that these aren't the reason. Rather, it's about the number of genetic mutations in mitochondrial DNA over time, which

differs between organisms, and the variation between cells caused by the mitochondria being randomly partitioned into daughter cells at each division."

In plants, mitochondrial mutations creep in slowly, so a germline isn't needed as mutations are corrected by natural selection. Mitochondrial variation is maximised by forming the next generation from the same cells used to make normal tissue cells. When the cells divide to form new daughter cells, some receive more mutant mitochondria than others and these cells are then removed through natural selection, preserving the reproductive cells containing higher quality mitochondria.

In mammals, genetic errors in mitochondria accumulate more quickly due to our higher metabolic rate so using cells that have undergone lots of division cycles would be a liability. Mitochondria are therefore only passed along to the next generation through a dedicated female germline in the form of large eggs. This protects against errors being introduced as eggs undergo many fewer replication cycles than cells in other tissues such as the gut, skin and blood.

The germline ensures that the best quality mitochondria are transferred but restricts the genetic variation in the next generation of cells in the developing embryo. This is corrected for by mammals generating far too many egg cells which are removed during development. For example, humans are born with over 6 million egg-precursor cells, 90% of which are culled by the start of puberty in a mysterious process called atresia.

Senior author, Dr Nick Lane (UCL CoMPLEX and Genetics, Evolution & Environment) added: "We think the rise in mitochondrial mutation rate likely occurred in the Cambrian explosion 550 million years ago when oxygen levels rose. This was the first appearance of motile animals in the fossil record, things like trilobites that had eyes and armour plating - predators and prey. By moving around they used their mitochondria

more and that increased the mutation rate. So to avoid these mutations accumulating they needed to have fewer rounds of cell division, and that meant sequestering a specialized germline."

Co-author, Professor Andrew Pomiankowski (UCL Genetics, Evolution & Environment), concluded: "Without a germline, animals with complex development and brains could not exist. Scientists have long tried to explain the evolution of the germline in terms of complexity. Who would have thought it arose from selection on mitochondrial genes? We hope our discovery will transform the way researchers understand animal development, reproduction and aging."

More information: Arunas L. Radzvilavicius, Zena Hadjivasiliou, Andrew Pomiankowski, Nick Lane, 'Selection for Mitochondrial Quality Drives Evolution of the Germline' *PLOS Biology*.

Provided by University College London