

Telomerase in Human Development

Telomerase is an enzyme that regulates the lengths of telomeres in the cells of many organisms, and in humans it begins to function in the early stages of embryonic development. Telomeres are repetitive sequences of DNA on the ends of chromosomes that protect chromosomes from sticking to each other or tangling. In 1989, Gregg Morin found that telomerase was present in human cells. In 1996, Woodring Wright and his team examined human embryonic cells and found that telomerase was active in them. Scientists manipulate telomerase in cells to give cells the capacity to replicate infinitely. Telomerase is also necessary for stem cells to replicate themselves and to develop into more specialized cells in embryos and fetuses.

Carol Greider and Elizabeth Blackburn discovered telomeres in 1978. Greider was Blackburn's student at the University of California in Berkeley, California. Blackburn had used the protozoan *Tetrahymena thermophila* to study telomeres in the process of cellular replication. In 1985 Greider and Blackburn discovered in *Tetrahymena* terminal transferase, which later was called telomerase. Greider and Blackburn found that telomerase was a type of enzyme that organizes DNA at the end of the strand in a reverse fashion from normal transcription. Scientists label any enzyme that follows the reverse pattern as a reverse transcriptase. Telomerase consists of protein and RNA that add thymine and guanine (TTGGGG) repeated nucleotide sequences on the ends of chromosomes. Telomerase fills a gap on the chromosome that exists due to imperfect DNA replication. DNA replication is imperfect because there is a space where the enzyme DNA polymerase detaches from the DNA strand.

In 1994 at the Cold Spring Harbor Laboratory in Cold Spring Harbor, New York, Lin Mantell and Greider showed that telomerase was necessary in germline and embryonic cells of developing frogs *Xenopus laevis*. For their work with telomeres and telomerase, Greider and Blackburn received the Nobel Prize in Physiology or Medicine in 2009, along with Jack Szostak.

Building upon the finding of telomerase in *Tetrahymena*, Gregg Morin studied if telomerase was present in human cells. In 1989, while working at Yale University in New Haven, Connecticut, Morin isolated telomerase from human HeLa cells. HeLa cells are named after Henrietta Lacks, a cervical cancer patient from whom the cells were taken. HeLa cells are cancerous cells that proliferate indefinitely. The telomerase that Morin found in the HeLa cells differed from the telomerase found in *Tetrahymena*. HeLa cells' telomerase had a six-nucleotide sequence of thymine, adenine and guanine (TTAGGG). Morin hypothesized that totipotent cells, or cells capable of becoming any types of cells such as embryonic stem cells, produced telomerase to retain the infinite replicative properties needed for an organism to develop.

Mantell and Greider verified Morin's hypothesis in *Xenopus* in 1994. Mantell and Greider found that during early development, telomerase is highly active. Telomeres were active throughout embryogenesis and oogenesis in *Xenopus* egg cells. The researchers also found that germline cells, such as cells found in the ovaries and testes of *Xenopus*, continued to produce telomerase. Mantell and Greider further suggested that telomerase functions in germline cells to preserve telomeres for future generations.

In 1996, scientists verified Morin's hypothesis in humans. Woodring Wright, Piatyszek Mieczyslaw, William Rainey, William Byrd, and Jerry Shay at the University of Texas Southwestern Medical Center in Dallas, Texas, performed an experiment that detected high amounts of telomerase activity in human blastocysts, and in tissues at sixteen to twenty weeks after fertilization. The activity rapidly declined and became undetectable after the neonatal period, or the first twenty-eight days of a child's life post-birth. Wright and his team concluded that the human body regulates and re-

presses telomerase activity after birth except in some tissues. Particularly, Wright's team found that telomerase was expressed in fetal, newborn, and adult testes and ovaries, but not in mature sperm or eggs, which differed from the results found in *Xenopus*. Wright and his team hypothesized that the difference was due to the fact that human sperm telomeres do not shorten with age, and human zygotes produce telomerase after the first cell division, therefore egg cells need not carry telomerase.

In 2001, researchers including Diane L. Wright at the Eastern Virginia Medical School in Norfolk, Virginia, found that telomerase is necessary for cells in human embryos to rapidly proliferate. Cells need telomerase during embryogenesis because as they replicate, their telomeres shorten. Without the presence of telomerase, the first few cells in the zygote would be unable to replicate and develop into an embryo and eventually a fetus. The scientists reported that telomerase was active in every stage of development of the embryo. They also observed that while telomerase activity was necessary for an embryo to develop, the amount of telomerase present did not predict the potential for embryonic growth.

Scientists found that genetic variation between humans influences telomerase activity during development and adult life. In 2010, researchers including Gil Atzmon at the Albert Einstein College of Medicine in Bronx, New York, published a study that explains the effects of telomerase in centenarians of Ashkenazi Jewish descent. That research showed that the centenarians and their offspring showed increased production of telomerase. Due to that increase, those studied had fewer than normal age-related diseases such as cardiovascular disease and diabetes mellitus, as well as other diseases caused by genetic mutations. The researchers named the genes associated with the increase in telomerase activity hTERT and hTERC. They further hypothesized that hTERT and hTERC became active during development and that their repression was not as drastic after birth for those studied as it was for those in a more general population.

Although scientists researched the link between telomerase activity and the process of how cells replicate, some criticized the way the data was produced. Critics of the research, such as Harry Rubin at the University of California, Berkeley, California, argued that the data collected on telomerase could be skewed by experimental techniques. Rubin argues that incorrect data of telomerase activity can result from tumor cells within the population or the result of a virus that causes overproduction of telomerase. Others argued that scientists over emphasized research into telomerase and telomeres and that other elements of development and the cell cycle are overlooked due to the attention given to telomeres.

Sources

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