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To prevent the loss of genes as chromosome ends wear down, the tips of

eukaryotic chromosomes have specialized DNA “caps” called ****telomeres****. Telomeres consist of hundreds or thousands of repeats of the same short DNA sequence, which varies between organisms but is 5'-TTAGGG-3' in humans and other mammals.

Telomeres need to be protected from a cell's [DNA repair systems](/science/biology/dna-as-the-genetic-material/dna-replication/a/dna-proofreading-and-repair" \t "_blank) because they have single-stranded overhangs, which "look like" damaged DNA. The overhang at the lagging strand end of the chromosome is due to incomplete end replication (see figure above). The overhang at the leading strand end of the chromosome is actually generated by enzymes that cut away part of the DNA.

In some species (including humans), the single-stranded overhangs bind to complementary repeats in the nearby double-stranded DNA, causing the telomere ends to form protective loops. Proteins associated with the telomere ends also help protect them and prevent them from triggering DNA repair pathways.

The repeats that make up a telomere are eaten away slowly over many division cycles, providing a buffer that protects the internal chromosome regions bearing the genes (at least, for some period of time). Telomere shortening has been connected to the aging of cells, and the progressive loss of telomeres may explain why cells can only divide a certain number of times.

## **Telomerase**

## Some cells have the ability to reverse telomere shortening by expressing ****telomerase****, an enzyme that extends the telomeres of chromosomes. Telomerase is an RNA-dependent DNA polymerase, meaning an enzyme that can make DNA using RNA as a template.

How does telomerase work? The enzyme binds to a special RNA molecule that contains a sequence complementary to the telomeric repeat. It extends (adds nucleotides to) the overhanging strand of the telomere DNA using this complementary RNA as a template. When the overhang is long enough, a matching strand can be made by the normal DNA replication machinery (that is, using an RNA primer and DNA polymerase), producing double-stranded DNA.

The primer may not be positioned right at the chromosome end and cannot be replaced with DNA, so an overhang will still be present. However, the overall length of the telomere will be greater.

Telomerase is not usually active in most somatic cells (cells of the body), but it’s active in germ cells (the cells that make sperm and eggs) and some adult stem cells. These are cell types that need to undergo many divisions, or, in the case of germ cells, give rise to a new organism with its telomeric “clock”

Interestingly, many [cancer cells](/science/biology/cellular-molecular-biology/stem-cells-and-cancer/a/cancer" \t "_blank) have shortened telomeres, and telomerase is active in these cells. If telomerase could be inhibited by drugs as part of cancer therapy, their excess division (and thus, the growth of the cancerous tumor) could potentially be stopped.