

## What are regeneration and regenerative medicine?

Regeneration is a natural process that allows plants and animals to replace or restore damaged or missing cells, tissues, organs, and even entire body parts to full function. Scientists are studying regeneration for its potential uses in medicine, such as treating a variety of injuries and diseases. Researchers also hope to learn more about the human aging process through studies of regeneration. This rapidly advancing field is called regenerative medicine.

## What organisms can regenerate?

All living organisms regenerate as part of natural processes to maintain tissues and organs. Some animals have extensive regenerative abilities. For example, the tiny freshwater animal called Hydra can form two whole bodies after being cut in half. The Axolotl, or Mexican salamander, is an animal with a backbone that can regenerate the form and function of almost any limb, organ, or other body part.

More complex animals such as mammals have limited regenerative capacities. These include forming thick scars in tissues and skin to promote the healing of injured or amputated body parts, regrowing hair and skin, and knitting together fractured bones.

## How do different organisms regenerate?

Organisms regenerate in different ways. Plants and some sea creatures, such as jellyfish, can replace missing parts by extensively remodeling their remaining tissues.

Some animals such as lobsters, catfish, and lizards replace missing parts by first growing a specialized bud of cells, called a blastema. These blastema cells rapidly divide to form the skin, scales, muscle, bone, or cartilage needed for creating the lost limb, fin, or tail.

In other animals, including humans, organs such as the liver undergo what is called compensatory hypertrophy. When part of the liver is removed or destroyed, the remaining portion grows to the original size and allows the liver to function as it did before. Our kidneys, pancreas, thyroid, adrenal glands, and lungs compensate for organ loss in a similar, but more limited, way.

[Research organisms](#) that are particularly useful for studying regeneration include the blue-and-white striped zebrafish and the planarian. The zebrafish can replace a damaged or lost fin, and can also repair significant damage to its heart, pancreas, retina, brain, and even spinal cord. The planarian, a freshwater flatworm, can regrow its entire body from a tiny fragment of its tissue. Humans have the same genes and pathways used by these animals that can regenerate damaged limbs and organs, but we do not have such extensive regenerative potential. The National Institute of General Medical Sciences (NIGMS) funds research to understand how regeneration works at the basic level, and why some organisms have more limited regenerative capacities than others. This research may allow humans to one day use our regeneration pathways to repair damaged hearts or to even replace lost limbs.



Scientists use several organisms with extensive regenerative abilities to study this naturally occurring process (clockwise from top left): Hydra, freshwater planarian, zebrafish, Axolotl (Mexican salamander). Credit: Hiroshi Shimizu, National Institute of Genetics in Mishima, Japan; Alejandro Sánchez Alvarado, Stowers Institute for Medical Research; Wikimedia Commons; Verdy Bratakusumah, NIH.

## What role do stem cells have in regeneration?

Stem cells have received some of the most intensive study related to regeneration. This is because stem cells can renew themselves millions of times. Other cells in the body, such as nerve cells, cannot do this. For example, adult stem cells are tissue-specific cells that also can replenish cells. Their primary roles are to maintain and repair the tissue in which they're found. Scientists are exploring whether a person's own stem cells could "grow" replacement tissue that wouldn't be rejected by the body's immune system.



Researchers used an [imaging technique called Skinbow](#) to better understand how zebrafish skin recovers after a scrape or amputation. The top image distinguishes hundreds of live cells from a tiny bit of skin on the tail fin of an adult zebrafish. The bottom image shows the cells on the outer surface of a scale. Credit: Chen-Hui Chen, Duke University.

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## How is regeneration related to aging?

Throughout an organism's life, its cells regenerate. But as part of the aging process, this ability gradually diminishes. To better understand the changes that occur, scientists are studying animals that show few signs of aging throughout their lifespans. Sea urchins, for example, can reproduce and regrow damaged parts throughout their lives. Because they maintain these abilities, sea urchins may help scientists answer questions about human aging as well as regeneration.

## What type of regeneration research does NIGMS support?

NIGMS-funded scientists are focused primarily on understanding the basic features of regeneration. For example, researchers are looking closely at where the cells involved in regenerated tissue originate. State-of-the-art imaging tools let them watch tissue regeneration in living animals, and genetic techniques allow them to systematically identify the genes involved in regeneration. Many scientists are working to better understand the unique properties of stem cells and their role in regeneration. Others are looking for chemical compounds that could be used as medicines to stimulate regeneration. Knowledge gained from these basic biomedical studies will provide a foundation for future clinical applications.

*NIGMS is a part of the National Institutes of Health that supports basic research to increase our understanding of biological processes and lay the foundation for advances in disease diagnosis, treatment, and prevention. For more information on the Institute's research and training programs, see <https://www.nigms.nih.gov>.*

## Learn More

### NIGMS Resources

[Blog Posts on Regeneration Using Research Organisms to Study Health and Disease](#) Fact Sheet  
[How Animals Offer Clues to Regeneration](#) Article  
[Understanding the Source of Regenerative Ability in Animals](#) Videocast

### Other Resources

[Tissue Engineering and Regenerative Medicine](#) Fact Sheet (NIBIB, NIH)  
Blog Post on [Regenerative Medicine: The Promise and Peril](#) (NIH)  
[Stem Cell Information](#) (NIH)  
[Regenerative Medicine Innovation Project](#) (NIH)  
[Regenerative Medicine](#)  (Partnership in Education)