National Institute of General Medical Sciences

Regeneration

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What are regeneration and regenerative medicine?

Regeneration is the natural process of replacing or restoring damaged or missing cells, tissues, organs, and even entire body parts to full function in plants and animals. 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 have some ability to 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.

This tiny freshwater animal Hydra can form two whole bodies after being cut in half. Credit: iStock

A Mexican salamander can regenerate almost any limb, organ, or other body part. Credit: iStock

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.
- Healing a bone fracture by using new tissue to knit the bone pieces together.

How do different organisms regenerate?

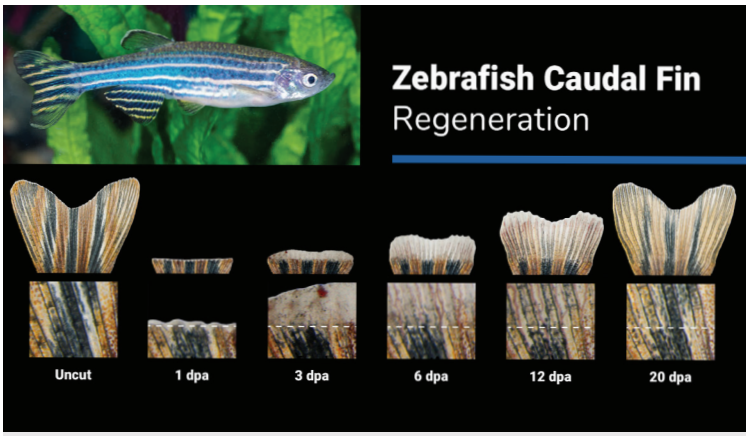
Organisms regenerate in different ways. Plants and some sea creatures, such as jellyfish, can replace missing parts by extensively remodeling their remaining tissues.

Some animals such as lobsters, catfish, and lizards replace missing parts by first growing a blastema. The 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's 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.

A planarian worm. Credit: iStock

Research organisms that are particularly useful for studying regeneration include the blue-and-white-striped zebrafish and the planarian, a type of flatworm. 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 regeneration of the fin on a zebrafish caudal over several weeks. Credit: Alejandro Sánchez Alvarado

The planarian uses organogenesis on a very large scale to regrow its entire body from a tiny fragment of its tissue if that piece of tissue contains one single neoblast. Humans have the same genes and pathways used by these animals; however, scientists don't yet fully understand how to turn on or start such extensive regeneration in humans.

The National Institute of General Medical Sciences (NIGMS) funds research to understand how regeneration works at the basic level, and why some organisms have less regenerative capacity than others. By studying regeneration in other species, scientists may learn more about how the human body heals and discover *our* regeneration pathways to repair damaged hearts or to even replace lost limbs.

What role do stem cells have in regeneration?

Stem cells play an important role in regeneration because they can develop into many different cell types in the body and renew themselves millions of times, something specialized cells in the body—such as nerve cells—cannot do. The primary roles of stem cells 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.

How is regeneration related to aging?

Throughout an organism's life, its cells regenerate. But as part of the aging process, this ability gradually declines. 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 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.

Scientist working in a lab. Credit: iStock

Learn More

NIGMS Resources

- **Regeneration** (*Biomedical Beat* blog posts)
- **Regeneration** (*Pathways*)
- **Research Organisms** (Fact sheet)
- **Understanding the Source of Regenerative Ability in Animals** (Videocast)
- **Glossary** (Pronunciations and easy-to-understand definitions)

Other Resources

- **Regenerative Medicine Innovation Project** (NIH videocast)
- **Skin Cells Can Be Reprogrammed In Vivo** (*NIH Director's Blog*)
- **Stem Cell Information** (NIH)
- **Tissue Engineering and Regenerative Medicine** (NIBIB)
- **Regenerative Medicine** (The Partnership in Education)