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Journal of Cell Science and Regenerative Medicine

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Volume 1, Issue 3 (July) 2025

Opinion

From Coral to CRISPR: Harnessing Marine Biology's Blueprint for the Next Wave of Regenerative Medicine

Sumit Kumar[1*,#], Akshatha Soratur[2,#], Ajit Kumar[2,#] and Ankit Sarkar[2,#]

[1]Department of Industrial Fish and Fisheries, Babasaheb Bhimrao Ambedkar Bihar University, Muzaffarpur 842001, India

[2]Department of Ocean Studies and Marine Biology, Pondicherry Central University, Port Blair 744103, India

[#]These authors contributed equally to this work.

Citation: Kumar S, Soratur A, Kumar A. From Coral to CRISPR: Harnessing Marine Biology's Blueprint for the Next Wave of Regenerative Medicine. *J Cell Sci Regenerative Med 2025;* 1(3): 114-115.

Received: 27 June, 2025; **Accepted:** 10 July, 2025; **Published:** 14 July, 2025

***Corresponding author:** Sumit Kumar, Department of Industrial Fish and Fisheries, Babasaheb Bhimrao Ambedkar Bihar University, Muzaffarpur 842001, India. Email: isumitvsingh@gmail.com

ABSTRACT

Coral reefs possess astonishing healing capabilities that could change medicine as we know it. In this review, we show how marine life, particularly corals, aid in tissues repair on the genetic and cellular level. This is achieved by using CRISPR technology, where scientists unlock methods of enhancing human regenerative therapies. These advancements provide opportunities for healing cartilage and nerve injuries, but also present ethical and environmental dilemmas. The struggles presented by climate change that is slowly destroying coral reefs make these attempts even more difficult. There is a need for cross-disciplinary inquiry to harness marine biology for medicine while conservation biology paradigms governs the investigation.

1. Introduction

Corals are often regarded as the world's coral reefs and just like the coriander plant, they are one of the few organisms that possess the ability to regenerate tissues and reconstruct skeletons as skeletal systems beautiful collapse, this "coral bleaching" facilitates unlocking unforeseen doors in the world of reconstructive medicine. On the other hand, coral's exquisite ability to rebuild during and after severe damage comes with drawbacks; the truth is confrontational and startling - the regenerative capabilities of corals pose a tremendous threat to a human's well-being because tissues repairing and scar sculpting is painfully intricate, resource draining and in terms of restoring bodily segments, considered nearly impossible, unlike dedicated marine scientists. It becomes daunting to fathom the extent of damage entail which CRISPR gene altering promises when interlaced with aquatic biology. These effortlessly mendable secrets encompassed by ocean life have the potential to alter medicine radically and disperse dire attention to protecting oceanic wonders before we lose them. Now, it becomes exponentially simpler to answer which evolves faster: humans or the ocean, fusing the contrast's regenerative portion of biology with coral's and marine organisms.

1.1. Historical perspective: Why marine biology has been overlooked

In the past, regenerative medicine has depended on terrestrial models such as salamanders, zebrafish and planarians which have been helpful in studying repair processes. These organisms, while helpful, do not possess the extremophytic traits decimating marine life possess. For example, corals flourish in low nutrient environments and withstand temperature fluctuations, conditions that might have triggered their regenerative prowess evolution mastery. This oversight is primarily due to the logistics of studying marine systems: requisitioning specialized aquarist for corals and having to carry out fieldwork in remote reefs makes studying corals harder. Fortunately, the logistics of studying marine organisms has become easier due to advances in sequencing technologies and CRISPR. A study by Nature Communications in 2021 demonstrated that coral stem cells make unique factors that inhibit scarring-this mechanism is not found in mammals. Likewise, the 2019 gene editing of hydra through CRISPR revealed conserved signaling pathways involved in tissue regeneration in humans. Traditional systems are limited and incorporating marine models could unlock unique healing pathways.

1.2. Marine organisms as regenerative powerhouses

Coral is an example of advanced regeneration capabilities, attributed to their symbiosis with algae (zooxanthellae) which helps in skeletal healing after the bleaching process. Acropolis corals have been shown to have stem and immune cells working cooperatively together to regenerate polyps under the guidance of calcium carbonate scaffold-placing genes. Other marine organisms also provide some additional perspectives. Blood stem cells are able to entirely remake the nervous system in sea squirts, a process qualitatively similar to human neurogenesis but leaves much to be desired in terms of efficiency. A starfish frees themselves from the shackles of a suboptimal limb count, with the help of a scattered host of almost completely unrecognized cells that regress back into basic cell types, while hydra age effortlessly through stem cell proliferation. Different from these examples, human biology is much simpler: the only regeneration possible is limited to surface interface healing (skin, liver) or relegating to scarring wounds. Marine systems accentuate the pliability of evolutionary systems of regeneration, hinting that we carry the trademark potential for profoundly systemized diverse changes that may be utilized through bio-mimicry **(Figure 1)**.

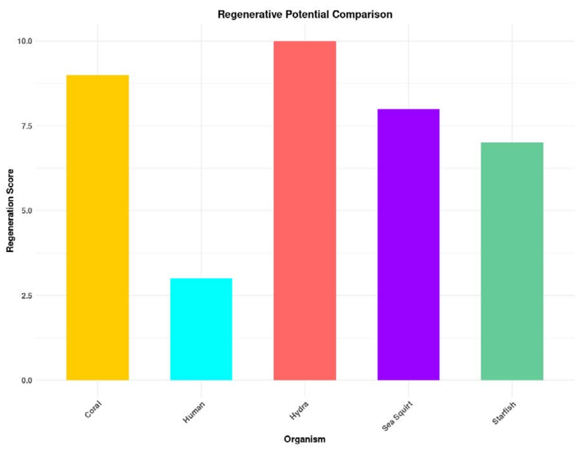

Figure 1: Comparative regenerative potential scores highlighting marine organisms' superior tissue repair capabilities versus human limitations, underscoring their biomedical research value.

1.3. The CRISPR connection

CRISPR-Cas9 has emerged as a powerful tool to dissect marine regenerative pathways. Researchers at the Australian Institute of Marine Science used CRISPR to knockout *Acropora* genes linked to skeletal repair, identifying transcription factors like *RUNX* that govern calcium precipitation. Similarly, CRISPR editing in hydra isolated the *Wnt/β-catenin* pathway, which regulates axial patterning-a conserved mechanism in human limb development. These discoveries enable scientists to engineer human stem cells with enhanced regenerative capacity. For instance, a 2022 study in *Science Advances* demonstrated that CRISPR-edited mesenchymal stem cells, inspired by coral-derived factors, improved cartilage regeneration in osteoarthritis models. By translating marine genetic blueprints into human therapeutic targets, CRISPR bridges the evolutionary divide, offering precision tools to replicate nature's regenerative strategies.

2. Ethical and Ecological Considerations

Although marine resources have promising potential in medicine, their pursuit is fraught with ethical and environmental concerns. Over-harvesting coral tissues for research, for example, can exacerbate the ongoing reef decline that is already worsened by ocean acidification and heating. This risk may be alleviated through synthetic biology methods such as lab-grown coral stem cell cultivation. Moreover, using live marine species for genetic engineering technologies to further human purposes raises the ethical concern of 'playing God' and alien repercussions on nature. For instance, modifying symbiotic genes of corals for better regeneration may enhance reef reefs but can alternatively wreak havoc on ecosystems. Balancing conservation and innovation creates a need for rigorous guidelines through interdisciplinary collaboration of marine biologists, ethicist and policy makers.

3. The Future of Marine-Inspired Regenerative Medicine

The fusion of marine biology and CRISPR could yield transformative therapies within a decade. Coral-derived growth factors may revolutionize treatments for osteoporosis by stimulating bone matrix formation. Starfish limb-regeneration pathways could inform spinal cord injury repair, while hydra-inspired stem cell therapies might combat neurodegenerative diseases. The U.S. National Institutes of Health has already funded initiatives like the "Coral to Clinic" program, aiming to translate marine discoveries into clinical applications. However, time is critical: coral reefs are projected to decline by 90% by 2050 under current climate trajectories. Preserving these ecosystems is not just an ecological imperative but a medical one; their loss could stall breakthroughs that might otherwise save millions of lives.

4. Conclusion

The ocean's corals and other marine organisms hold a genetic toolkit that could redefine human healing. By leveraging CRISPR to decode their regenerative secrets, scientists stand at the threshold of a medical revolution-one that mimics the resilience of reef ecosystems to mend human bodies. Yet this potential hinges on urgent conservation efforts and ethical foresight. As climate change threatens both marine biodiversity and human health, the convergence of coral biology and CRISPR offers a poignant reminder: the future of regenerative medicine may lie not in labs alone, but in the depths of the ocean we are racing to protect. The key to healing humanity might just be hidden in the waves.

5. Acknowledgment

None

6. Conflict of Interest

No conflict of interest.