Lessons from the sea: Sea urchins as models for aging and cancer research

NEB has long recognized the potential of the marine environment as a source for new discovery and the need to protect and preserve the ocean’s vast biodiversity for the benefit of humankind. The unique adaptations of marine organisms have made them valuable models for biomedical research, provided novel therapeutics for human disease and uncovered new tools to advance biotechnology. Located just 12 miles from NEB’s headquarters in Ipswich MA, a new marine biotechnology institute, Gloucester Marine Genomics Institute (GMGI), is applying innovative genomic technologies to marine science for discoveries that impact human health, biotechnology and fisheries. In February, GMGI’s Science Director, Dr. Andrea Bodnar, visited NEB to provide an overview of the research programs at GMGI and to present some of her work using sea urchins as models to unlock the secrets of living a long and healthy life.

Understanding Extreme Longevity

The oceans are home to many of the Earth’s longest-lived animals with several non-colonial marine invertebrates and vertebrates documented to live for more than 100 years (Table 1) (1–8). Many of these animals grow and reproduce throughout their lifespans with no apparent functional decline, no increased incidence of disease or increase in mortality rate with age. A better understanding of the mechanisms by which these animals achieve their extraordinary life histories may reveal exceptionally effective defenses against the destructive process of aging and suggest novel avenues to prevent or treat human age-related degenerative diseases. The red sea urchin is among the Earth’s longest-lived animals, estimated to live for more than 200 years without evidence of age-related decline and no reported cases of cancer (6,7,9). Sea urchins have served as model organisms for scientific research and evolutionary studies (14). Human aging is accompanied by the shortening of telomeres (caps that protect the ends of chromosomes), accumulation of cellular oxidative damage, and reduced ability to repair and replenish damaged tissues. In contrast, sea urchins maintain their telomeres (15,16), have little accumulation of oxidative damage (17) and maintain their growth, survival, longevity, susceptibility to disease and reproductive patterns as this information is essential for effective fisheries management (10). From these data it has been noted that different species of sea urchins exhibit very different natural lifespans in the wild. While the red sea urchin (Mesocentrotus franciscanus) is reported to be very long-lived, the purple sea urchin (Stronglyocentrotus purpuratus) has an estimated maximum life expectancy of more than 50 years and the variegated sea urchin (Lytechinus variegatus) has an estimated life expectancy of about 4 years (6,7,11–13). Comparisons between long-, intermediate- and short-lived species provide an excellent model to understand mechanisms of lifespan determination and can provide insight into how these animals avoid the process of aging.

Aging is a complex and multifactorial process and there have been many theories proposed to explain this phenomenon at the molecular, cellular, systemic and evolutionary levels (14). Human aging is accompanied by the shortening of telomeres (caps that protect the ends of chromosomes), accumulation of cellular oxidative damage, and reduced ability to repair and replenish damaged tissues. In contrast, sea urchins maintain their telomeres(15,16), have little accumulation of oxidative damage (17) and maintain the ability to continually regenerate lost or damaged appendages throughout their lives (18). In most animals, there is a delicate balance between promoting cell renewal and regeneration for maintaining healthy tissues, and the danger of unchecked, abnormal cell growth that defines cancer. Notably, there are no documented cases of cancer in sea urchins (19,20). The ability of sea urchins to continually grow and regenerate while apparently resisting cancer holds great promise for discovering naturally occurring cancer prevention mechanisms.

Initial studies with sea urchins have demonstrated that the circulating cells (coelomocytes) are highly resistant to DNA damaging agents, invoke a robust DNA repair response and can effectively repair DNA damage (21,22). However, more study is required to determine if the high resistance to DNA damage in sea urchin cells contributes to the low incidence of cancer and to understand the cellular mechanisms protecting DNA.

At GMGI, our goal is to use sea urchins and other long-lived marine animals as models to identify the key genes and cellular pathways involved in long-term maintenance of tissues and resistance to cancer. Insight gained from studying exceptional longevity in sea urchins may reveal novel strategies to slow the destructive process of aging and identify new avenues for prevention or treatment of age-related diseases such as cancer.

Dr. Bodnar would like to thank Dr. Barton Slatko for the invitation to participate in NEB’s seminar series.

REFERENCES


LONGEVITY IN NON-COLONIAL MARINE ANIMALS

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
<th>Oldest Recorded Lifespan (Years)</th>
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<tbody>
<tr>
<td>Ocean quahog clam</td>
<td>Arctica islandica</td>
<td>500</td>
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<tr>
<td>Greenland shark</td>
<td>Somnusomus microcephalus</td>
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<td>Marine tubeworm</td>
<td>Lamellibrachia sp</td>
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<td>Bowhead whale</td>
<td>Balaena mysticetus</td>
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<td>Roughy rockfish</td>
<td>Sebastes aleutianus</td>
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<tr>
<td>Red sea urchin</td>
<td>Mesocentrotus franciscanus</td>
<td>200</td>
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<tr>
<td>Geoduck clam</td>
<td>Panopea abrupta</td>
<td>180</td>
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</tbody>
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Founded in 2013, Gloucester Marine Genomics Institute is a 501(c)3 with a mission to conduct world class marine biotechnology research which expands the regional economy.