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How Symbiotic Bacteria Brew Steroid Hormones to Help Corals Survive Extreme Ocean Heat

Coral Reefs * Marine Biology * Microbiome

When ocean temperatures climb by just one or two degrees Celsius above normal summer highs, most tropical coral reefs face a life-threatening crisis. Stressed by the heat, corals expel the colorful microscopic algae living inside their tissues -- a phenomenon known as coral bleaching -- and often starve or succumb to cellular damage if the water does not cool down.

Yet in the shallow waters of the Arabian Gulf off the coast of Abu Dhabi, reef-building corals routinely survive summer water temperatures exceeding 34 deg C to 36 deg C (93 deg F to 97 deg F) -- heat levels that would rapidly kill corals on the Great Barrier Reef or in the Caribbean. Now, in a landmark study published in Nature Microbiology (DOI: 10.1038/s41564-026-02494-1), a team of scientists at New York University Abu Dhabi (NYUAD) led by first author Amin R. Mohamed and senior author Shady A. Amin has uncovered a surprising biochemical secret behind this heat resilience: beneficial bacteria living inside the coral brew human-like steroid hormones -- specifically progesterone and testosterone -- to protect their coral hosts during extreme heatwaves.

More Than Animal and Algae: Inside the Coral Holobiont

Although a coral reef looks like colorful underwater rock built by tiny anemone-like animals called polyps, biologists view every coral as a holobiont -- a closely knit biological community made up of the coral animal, its internal photosynthetic algae (which use sunlight to make sugars for the coral), and a bustling neighborhood of bacteria, fungi , and viruses.

For decades, marine biologists focused almost exclusively on the partnership between the coral animal and its photosynthetic algae. However, healthy corals around the world also harbor dense clusters of a specific group of bacteria called Endozoicomonas tucked deep inside their tissues. Whenever a reef suffers severe bleaching or disease, Endozoicomonas populations mysteriously plummet, whereas heat-tolerant corals tend to maintain rich colonies of these microbes. Despite this clear link to coral health, nobody knew exactly what Endozoicomonas was doing to keep corals alive during marine heatwaves.

| Biological Component / Metric | | Role in the Coral Holobiont | | Response During Extreme Heat Stress |

| Arabian Gulf Thermal Baseline | | Natural laboratory for extreme marine warming | | Corals endure summer peaks of 34 deg C-36 deg C (vs. 30 deg C-31 deg C global bleaching thresholds) |

| Symbiotic Microalgae (Symbiodiniaceae) | | Supply up to 90% of the coral's daily energy via photosynthesis | | Produce damaging reactive oxygen molecules when overheated, triggering coral bleaching |

| Endozoicomonas Bacteria | | Dominant bacterial symbiont living inside healthy coral tissues worldwide | | Convert host cholesterol into progesterone and testosterone during heat stress |

| Microbial Steroid Hormones | | Chemical messengers shared between bacteria and coral cells | | Calm runaway immune inflammation, lower oxidative damage, and increase coral cell survival |

| Conservation Application | | Next-generation "coral probiotics" for reef restoration | | Selecting steroid-producing bacterial strains to inoculate heat-vulnerable nursery corals |

A Microbial Hormone Factory Under Heat Stress

To decode the chemical conversation between corals and their resident bacteria, the NYU Abu Dhabi researchers -- including marine microbiologist Michael A. Ochsenk hn and coral ecologist John A. Burt -- collected corals from the thermally extreme reefs of the Arabian Gulf and analyzed both their bacterial DNA (metagenomics , which reveals all the genetic blueprints present in a microbe) and their small chemical molecules (metabolomics).

Under normal temperatures, the coral animal naturally synthesizes its own steroid hormones from cholesterol to regulate growth, reproduction, and tissue repair. When water temperatures spike, however, the exhausted coral animal shuts down its own hormone-making machinery to conserve energy. At that exact moment, the team discovered, the resident Endozoicomonas bacteria switch on specialized enzymes that absorb cholesterol and steroid building blocks from the coral and convert them into active progesterone and testosterone .

Until recently, scientists thought the ability to manufacture steroid hormones like testosterone and progesterone was almost exclusively restricted to complex plants and animals (eukaryotes), with only a handful of specialized bacteria in the human gut known to modify steroids. Finding a marine bacterium that actively synthesizes these hormones inside an ancient invertebrate animal revealed an evolutionary partnership hiding in plain sight.

How Progesterone and Testosterone Save Overheated Coral Cells

Why would a coral need steroid hormones in the middle of a heatwave? When ocean temperatures soar, stressed coral cells and their internal algae begin leaking destructive chemical sparks called reactive oxygen species (ROS) -- the biological equivalent of cellular rust. In response, the coral's innate immune system (its built-in frontline defense network) can overreact, triggering runaway inflammation and programmed cell death that causes the coral to strip away its own tissues and expel its algae.

To test what the bacterial hormones actually do, the NYUAD team exposed isolated coral cells and live coral fragments to elevated temperatures in the laboratory while supplying them with the purified steroid hormones produced by Endozoicomonas . The results were striking:

* Calming the Immune Alarm: Progesterone and testosterone acted as molecular peacekeepers, reprogramming the coral's immune genes so the cells mounted a

balanced, protective stress response instead of self-destructive inflammation.

* Boosting Cellular Survival: Coral cells treated with the bacterial steroid hormones maintained higher energy reserves, suffered significantly less oxidative damage, and survived heat exposure at much higher rates than untreated cells.

Engineering Probiotics for Warming Reefs

As global ocean temperatures continue to rise, marine conservationists are racing to develop practical tools to help vulnerable reefs survive summer heatwaves. In recent years, researchers have begun testing coral probiotics -- beneficial cocktails of natural reef bacteria sprayed onto corals in underwater nurseries or wild reefs, much like yogurt probiotics support human digestion.

By pinpointing the exact chemical mechanism that makes Endozoicomonas so protective -- its ability to turn cholesterol into immune-calming steroid hormones when the coral's own hormone production falters -- the NYU Abu Dhabi discovery gives reef restoration teams a clear biological marker to screen for the most effective heat-shielding bacterial strains before transplanting young corals back onto warming reefs.

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