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# Designer corals shine a bright light on the future of coral reefs

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*Coral reefs are in rapid decline due to climate change, which causes marine heat waves. We cultured the microalgae that live inside the coral tissue under high temperature for four years. When we reintroduced the heat-evolved microalgae into coral, some of these "designer" corals showed increased tolerance to heat. Such coral may be used to help coral reefs survive until climate warming is halted.*

*Image credits: Chris Jones*

Our climate is warming rapidly and this poses the greatest threat to coral reefs. Climate change not only causes a gradual increase in average water temperatures, but also an increased frequency, intensity and duration of summer heat waves. Over the last five years, three heat waves have diminished corals on the Great Barrier Reef to less than half.

The only solution to the threat on coral reefs is strong action on climate warming. However, to ensure corals survive until such time, additional interventions are required. Two approaches are currently being explored, the first aims to reduce heat stress by cooling or shading of the reef, and the second harnesses natural biological mechanisms to increase coral heat tolerance. The latter is the focus of our research.

Corals form a close association with microalgae that live inside their cells. The microalgae use the sun's energy, carbon dioxide and water to make sugars, a large portion of which they send into the coral tissues. Corals receive most of their energy from the microalgae and depend on them for their survival. This symbiosis is, however, bound to a narrow temperature range. Marine heat waves cause a breakdown of the association between coral and microalgae, resulting in the loss of the microalgae from the coral tissues; this is called coral bleaching.

If the association is not re-established, the corals will starve and eventually die.

Our approach to increasing coral heat tolerance is based on bolstering the heat tolerance of the corals' natural microalgae in the lab and then reintroducing the heat-evolved microalgae into the coral. For this purpose, we gradually increased the culture temperature of the microalgae species of our focus, from ambient (27°C) to high (31°C) and then kept the temperature at 31°C for four years.

Over these four years, random changes will have occurred in the genome of the microalgae, as the cell machinery makes occasional mistakes when copying its DNA during every cell division. We hypothesized that the high culture temperatures will result in selection for beneficial genetic mutations. After four years, we allowed the evolved microalgae to associate with coral larvae. We then subjected these "designer" corals to a simulated summer heat wave in the lab.

Some "designer" corals did not cope well with the hot water; they bleached and some larvae died. The same was seen for the larvae that were paired with the microalgae that had been kept at 27°C for the four years. But three coral-microalgae pairings were more tolerant and did not bleach during the lab-simulated heat wave.

To explore the genetic adaptations that had occurred during the period that the strains were exposed to high temperature, we studied changes in gene activity. The heat-tolerant pairing showed a higher activity of microalgal genes related to the conversion of carbon dioxide into sugars, while genes involved in capturing sunlight and turning it into forms of energy the cell can use (photosynthesis) were turned down.

During photosynthesis, different toxic byproducts are naturally created in the cell. Some of these toxic byproducts are produced in excess during summer heat waves and drive the loss of the microalgae from the coral tissues. It is possible that the lower rate of photosynthesis reduces the amount of toxic byproducts. The higher carbon fixation activity likely compensates for the lowered rate of photosynthesis and keeps the coral fed.

We also explored whether the activity of coral genes changed in the new pairings. Because the coral larvae in each pairing were genetically similar, we can be sure that changes in coral gene activity were a result of the different microalgal strains. We found that known coral heat response genes were more active in the heat-tolerant pairing, even before the larvae were exposed to heat. This means it has a naturally higher level of stress response gene products, likely making it better able to cope with heat stress.

Our findings show that heat evolution of microalgae in the lab, followed by their reintroduction into coral, can increase coral heat-tolerance and thus protect them from bleaching. Such "designer" corals could assist corals in coping with summer heat waves until we curb climate warming.