A 'crystal ball' for predicting the effects of global climate change

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In trying to predict how species will respond to climate change caused by global warming, researchers and scientists are turning to comparative physiology, a sub-discipline of physiology that studies how different organisms function and adapt to diverse and changing environments. By comparing different species to each other, as well as to members within a species that live in different environments, researchers are learning which physiologic features establish environmental optima and tolerance limits. This approach gives the scientific community a "crystal ball" for predicting the effects of global warming, according to George N. Somero, Associate Director of Stanford University's Hopkins Marine Station.

Dr. Somero will discuss the benefits of the comparative approach at the 2010 American Physiological Society's Intersociety Meeting in Westminster, Colo., August 4-7. He will deliver the plenary lecture of the conference, entitled Global Change and Global Science: Comparative Physiology in a Changing World. The lecture will focus on work done by his team and others with ectothermic marine species—species whose body temperatures change in response to their environment and are commonly referred to as "cold-blooded."

Heat's Effect on Adaptation in Porcelain Crabs

According to Dr. Somero, the comparative approach can provide insight into the ways in which past evolution under different climatic conditions determines a species' likelihood of survival in a warming world. For example, thermal tolerance limits—the highest and lowest temperatures at which an organism can survive—differ among closely related species of porcelain crab: Tropical species are far more heat-tolerant than their counterparts in temperate climates.

One might expect the heat-tolerant tropical crab to have an advantage over their temperate cousins when it comes to adaptability to climate change. Comparative physiology has shown that this is not the case, however.

According to Dr. Somero, "Tropical porcelain crabs, which live at high temperatures, live right near the edge of their thermal tolerance range, and they have little ability to further increase their thermal tolerance by acclimation." Therefore, even though this tropical crab species can handle higher temperatures compared to the temperate crab species, the tropical species is close to reaching the tipping point for coping with additional increases in temperature. Thus, the tropical crabs have less of a margin for adaptation to warm climates while the temperate counterparts have more room to adapt.

"Researchers can predict that tropical species of porcelain crabs will be more vulnerable to climate change than temperate ones," said Dr. Somero. "Furthermore, the lessons we've learned from studying these marine crabs appear to apply not only to other marine animals, but also to terrestrial species."

Protein and Adaptation to Climate Change

The Somero team is also looking at the role proteins play in an organism's ability to adapt to climate change. Proteins, which provide much of the structure of organisms and drive all metabolic reactions, are highly sensitive to temperature. The abilities of proteins to evolve rapidly in the face of climate change will affect a species' chances of survival. "If proteins don't adapt, organisms will function at a sub-par level," said Dr. Somero. "Individual organisms may not die immediately, but over time, entire populations can die off."

The more abundant the number of adaptive sites that exist on a protein, the more easily that protein can undergo adaptive change. Comparative studies of proteins common to diverse species of fish and invertebrates have shown that only a single change in structure (one amino acid is substituted for another) can be sufficient to adapt a protein to a new temperature. Comparative studies must now determine how many different types of proteins will need to adapt to the predicted changes in temperature due to climate change and how much adaptive variation already exists in natural populations.

Genomic Studies: Sublethal Stress and Deficient Genetic "Tool Kits"

The comparative physiology approach extends to genomics. DNA microarrays, also known as "gene chips," enable researchers like Dr. Somero to compare thousands of DNA molecules from different species. This allows them to identify which genes are involved in the way a species reacts to the stress of climate change.

"When we look at what genes are turned on by sub-lethal temperature stress—not enough to kill the organism but enough to cause a problem—we can get a sense of the damage that is occurring in the cells," he said.

Such damage takes a heavy toll, he added. "It's a drain on the organism's energy supply. The organism has to channel energy into repairing the damage instead of into growth and reproduction."

Genomic studies are also revealing differences among species in the sets of "tools" found in their genomic "tool kits." The news for certain species may be grim: Comparing genomes has revealed that long-term evolution at stable temperatures may have stripped certain species of their ability to adapt to warming.

"This is particularly true in the Southern Ocean, where the consequences of evolving in an extremely cold and very stable thermal environment over a period of 10 to 15 million years are dramatic," said Dr. Somero. "The genes needed to allow these organisms to cope with rising temperatures may have been lost during evolution under stable cold conditions." Ectotherms of the Southern Ocean may be the most threatened of all marine species by rising temperatures.

Overall, the comparative approach gives researchers insights into the effects of global warming that they wouldn't otherwise have, said Dr. Somero. "Only by studying species adapted to different temperatures can we identify the mechanisms that underlie temperature-sensitivity and thus set the capacities of organisms for dealing with climate change," he said. "Comparative physiological analysis thus can help us determine how a warming world will affect the structure of our ecosystems. It will help us predict which organisms will be forced out and which will continue to thrive."

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