An Australian thorny devil takes an unconventional drink as it stands in a puddle.

Desert Lizards Get a Skinful

BY DANENE JONES

New research reveals how Australian thorny devils and Texas horned lizards harvest rainwater with their skin.

Australians may be facing drastic water shortages, but two desert-dwelling lizards have found a novel approach to life in a dry climate.

Scientists have known for years that the Australian thorny devil, *Moloch horridus*, has the remarkable ability to move water from the ground into its mouth using only its skin. Recent research, however, sheds new light on the details of water transport in the thorny devil and Texas horned lizard (*Phrynosoma cornutum*). It appears semi-tubular channels lie at the base of the lizards' scale hinges.

"We didn't expect what we found at all," says Wade Sherbrooke, a former director of the American Museum of Natural History's Southwest Research Station in Arizona.

Sherbrooke and colleagues from James Cook University in Townsville employed scanning electron microscopy on cross-sections of scales to study in detail the mechanisms of water transport in the desert-dwelling lizards. Their investigations uncovered similar features in the unrelated lizards – one is an agamid, the other an iguanid – that suggest convergent evolution may have occurred.

Cross-section through a semi-tubular channel at the base of a scale hinge joint. The channel opens to the right onto the surface of the lizard's skin.

A Pool of Research

In the 1920s, scientists assumed that thorny devils had the power to absorb water through their skin after placing the lizards in a saucer of water. Reptilian skin is unlike that of amphibians, however, and any ready uptake of water across the epidermis would likely result in a similar loss of water in a reverse process. "Reptilian skin is designed to keep water in so the animals don't desiccate," says Sherbrooke.

Researchers in the 1960s realised as much, and began hypothesising about other ways water uptake and transport in thorny devils could occur. Dyed water was observed moving over the surface of the skin, leading scientists to believe that water moved via open microchannels in the outer keratinised layers of scales. Later studies, however, suggested that the movement of water occurred between scales rather than over them.

Up Close with a Devil

Twenty odd years later, Sherbrooke and colleagues decided to take a closer look at the scales of the thorny devil.

The surface of a thorny devil consists of large spines and smaller scales. The epidermis also has an outer and inner layer of keratin, and the two layers are separated by mesos. Within the mesos layer are extracellular lipids that serve as an impermeable water barrier to help the lizards retain body fluids.

Scales are fixed to the body by a lace-like network of scale hinges, providing flexibility to the surface. Cross-sections revealed a widening of the base of the scale hinges, thereby forming a semi-tubular channel.

"No one hypothesised that these scale hinges were shaped like this," says Lin Schwarzkopf, who offered her lab and participated in the study.

Sherbrooke's curiosity was piqued and, at his request, his visiting sister loaded her suitcase with some Texas horned lizard specimens he had used in previous studies back in the United States. Some lengthy explanations with the Australian Customs Service ensued, but comparisons between the water-uptake abilities of thorny devils and horned lizards were soon underway.

Like thorny devils, horned lizards live

Wade Sherbrooke holding a regal horned lizard, a Sonoran Desert relative of the Texas horned lizard.

in a dry habitat and use their skin to harvest rain. Further similarities emerged during the study, which showed that the hinge joints of horned lizards also widen to form a semi-tubular channel.

Water Uptake

The channels in both species of lizards are approximately the width of one or two human hairs, and exist beneath an even narrower opening in the scale hinges. Within the expanded hinge-joint spaces are "islands" of bulging tissue.

The narrow opening of the scale hinges creates capillary forces that draw water into the hinge-joint channels. The protrusions within the channels increase surface area and enhance the attraction between the surfaces and water, thus helping to draw in more water.

The semi-tubular channels ultimately form a continuous hinge-joint network across all areas of the lizards' skin – from head to toe. The multiple menisci formed spread water throughout the entire network of channels, and may enhance the speed at which water is transported.

During heavy rain, horned lizards forego capillary action in favour of a rain-harvesting stance. With head and tail pointing downwards, water drips from the nose of the horned lizard and is captured by the mouth. The stance is not used by thorny devils, which may rely entirely on capillary action to collect water during and after rain.

Some mystery remains, however, as to how the water makes its way to the mouth during light rain. Capillary forces are not sufficient to move water once the scale-hinge system is full. Chemical factors in oral mucous were previously thought to assist water ingestion, but the new research indicates otherwise.

Both species have modified surface structures, including scales, at the rear of the jaws. Water ingestion in horned lizards is via the rictal plate (a fold of skin between the upper and lower lips), which folds in when the mouth is closed. The rictal plate has micro-ornamentations similar to those found in the scale-hinge joint. Thorny devils possess no such skin fold, but furrows are apparent on the scales at the back of the jaw. A screen of tissue is also suspended from the upper jaw.

Sherbrooke is uncertain about the precise roles played by these mouth structures, but believes that they each serve a function in water ingestion. What is more apparent, and has been closely observed in previous studies, is the opening and

Texas horned lizards have a broad body that they arch, with head and tail pointing downward, when in a rain-harvesting stance.

closing of the mouths of thorny devils and horned lizards during skin-assisted drinking – a movement that occurs approximately once per second.

Sherbrooke and his colleagues suggest that a negative pressure is generated at the jaw and in the mouth by jaw and tongue movements. That negative pressure may transfer to the entire water-filled system, and be enough to overcome the drag of water against channel walls and draw water towards the mouth.

Convergent Evolution

Scientists have long suspected convergent evolution between thorny devils and horned lizards. Both eat ants, have spines and similar colouration, and are able to rapidly transport water over their skin. Until now, however, details concerning the structural convergence of water collection systems were lacking.

Sherbrooke and his colleagues decided to study and compare other lizard species from the same families against thorny devils (agamid) and horned lizards (iguanid). If convergence in water transport structures were at work, then relatives of the desert-dwelling lizards would not have the same features as the specialised pair.

Observations of these other species showed they were not able to transport water, or could only do so slowly. The researchers then took a closer look at the water transport structures of the relatives and found that all agamids and iguanids studied lacked semi-tubular channels. As Schwarzkopf notes, thorny devils and horned lizards have unique modifications for rapid water transport.

The similarities between thorny devils and horned lizards, coupled with the absence of such features in related lizards, strongly suggests that convergent evolution may be at work to help these desert-dwellers deal with their dry habitats.

Sherbrooke hopes to unravel further mysteries about the rain-harvesting capabilities of horned lizards, particularly their mouth structures. Until then, the details of his latest study may well have applications in other fields, including the development of materials with a microstructure similar to the skin of thorny devils and horned lizards.

That's no water off a lizard's back.

Danene Jones is a graduate student at the Australian National University, and a member of the Shell Questacon Science Circus. The work described was done by Dr Wade Sherbrooke, retired director of the Southwest Research Station, Drs Lin Schwarzkopf and Andrew Scardino, and Prof Rocky de Nys from James Cook University's School of Marine and Tropical Biology.