# Cactus spines, sharper than you may think!

*Philip Robinson*

Oil spills at sea, such as the *Deepwater* Horizon oil spill in the Gulf of Mexico in 2010,[1] can be massively damaging ecological events, with oil spreading for many thousands of miles. Biomimetics, the abstraction of good design from nature,[2] is again providing a useful solution,[3] this time to such disasters. Recently published cactus-inspired research[4] is aimed at finding a more effective way of capturing submerged oil droplets, which are normally missed in the cleanup operations, which typically focus on collecting the oil near the surface of the water.

### A unique system

The new technology builds upon previous research[5] on the tapered spines[6] of the cactus species, *Opuntia microdasys* (figure 1), which is endemic to central and Northern Mexico, and found in places such as the arid Chihuahua Desert. It was discovered that the cactus efficiently collects water droplets from fog using a "unique system composed of well-distributed clusters of conical spines and trichomes on the cactus stem".[7] This occurs because the cactus spines have an interesting effect on the water droplets. When micron-sized spherically shaped water droplets in the air land on them, the spine's conical shape distorts them, forcing them into a clam-like shape instead. However, water droplets are inclined to be spherical, and exert a strong inward pressure to try and remain so. In opposition the surface tension wants the water droplet to be in the clam-like shape. The battle between these two forces pushes the droplets from the tip of the spine[8] toward the cactus plant at the base of the spine, where the spine's surface is less curved and the radius is larger.[9] The cactus's trichomes at the base of the spine then immediately absorb the droplets of water.

Cactus spines have many different functions, such as offering protection, shade, and slowing down air currents around the epidermis to lessen water loss. The discovery of this new function, added to the CAM physiology,[10] waxy skin, succulent tissue, and specialized root system, are a wonderful example of design that had to be present and functional to allow the cactus to live in such harsh ecosystems as the Chihuahua Desert.

### Collecting oil droplets in water

Inspired by the research on the newly discovered function of the cactus spines, the design was mimicked and applied to collecting oil droplets in water. While oil normally floats on water, oil spills also produce some denser micron-sized droplets as the oil breaks down, which don't float on the surface. The current range of cleanup technologies used on oil spills such as mechanical skimmers or membrane filters mainly remove oil from the surface but miss those denser droplets that have sunken further down.

To tackle the problem, a team of scientists in Beijing identified that "micron-sized oil droplets in water and micron-sized water droplets in air are similar, so we can move the cactus-inspired system underwater".[11] This was done by creating arrays of conical copper and silicone polymer-based[12] needles to replicate the cactus spines. "The ability to deposit oil is based on the intrinsic oleophilicity[13] of these materials under water, and the canonical structure induces the directional motion of the collected oil droplets."[14] The arrays were then

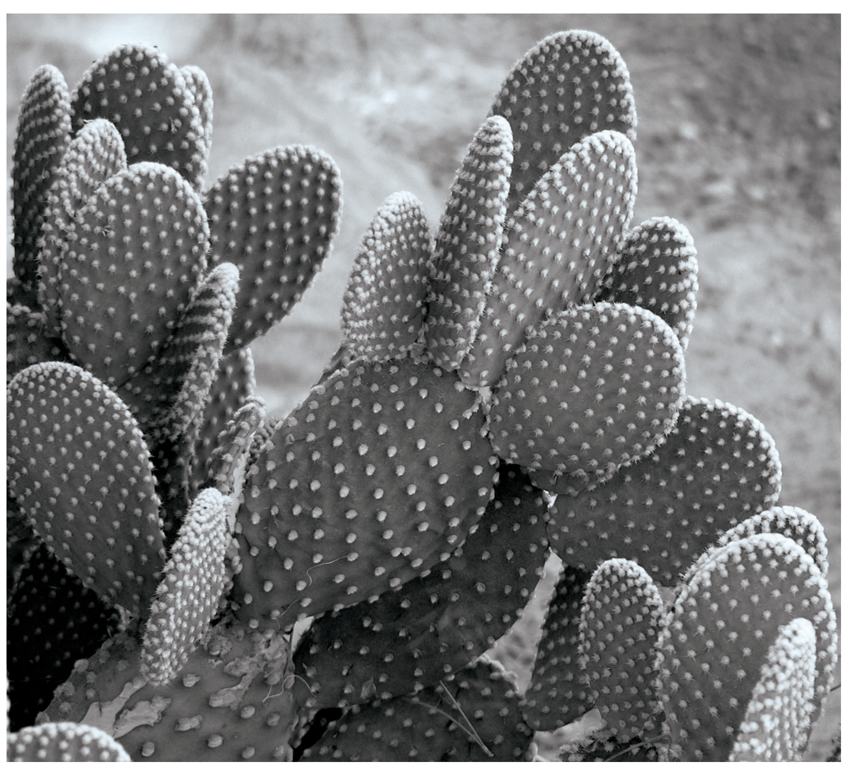

**Figure 1.** The cactus *Opuntia microdasys*.

### Thorns and thistles—degenerative mutations or divinely designed?

Astute long-time readers of CMI publications may have noticed something of an apparent contradiction between the theme of this perspective article and that of a previous Creation Magazine article: "A Thorny Issue".[19] I have put forward in this article that the cactus spine is not simply a degenerative mutation but specially created by God as part of the Curse in Genesis 3. Scripture suggests that as part of the Curse genetic changes took place: a permanent change to the serpent; pain during child birth; and the introduction of thorns and thistles.[20] There are great differences in modern names applied to the all-encompassing "thorns and thistles" in Genesis 3: thorns, prickles, bristles, spines, etc. While what may appear to be a degenerative mutation[21] may explain one or more of these categories—most likely thorns and prickles due to their fairly simple formation, structure, and position—it surely does not, and cannot, explain them all due to their individual complexities, differences, and functions. While it has been suggested that cactus spines are mutated leaves, the indication taken from Scripture and their actual formation would suggest that they are not. The cactus researcher Mauseth describes the difference in the formation of cactus spines and the cactus leaf,

"Evolution appears to have been more complex than would be expected: mature cactus spines do not contain any of the cells or tissues characteristic of leaves, and conversely leaves lack all features characteristic of spines. The two organs have little in common other than developing from leaf primordia. Spines consist of just a core of fibers surrounded by sclereid-like epidermis cells. They have no stomata, no guard cells, no mesophyll parenchyma, no xylem, no phloem. When mature, all cells in a spine are dead, and even when the spine is still growing it has living cells only at its base. Cactus leaves on the other hand —even the microscopic leaves of Cactoideae—have parenchymatous epidermis cells, guard cells, spongy mesophyll, chlorenchyma, xylem, and phloem. So the evolutionary conversion of cactus leaves into spines did not involve a mere reduction of the lamina and then further reduction of midrib and petiole, it instead involved the suppression of all leaf-cell-type genes and activation of genes that control formation of fibers, the deposition and lignification of secondary walls, and then programmed cell death. These fiber morphogenesis genes are not activated in any cactus leaf (none at all has fibers), but they are activated of course in the development of wood. It would appear that after an axillary bud apical meristem initiates spine primordia, most leaf genes remain suppressed and instead wood fiber genes are activated. This does not involve all wood genes because vessels are never produced in the spines, just wood fibers."[22]

While Mauseth has incorrectly attributed the formation of the cactus spine to evolution, what should be abundantly clear from his description is that the attribution of a naturalistic degenerative mutation for the formation of a cactus spine cannot be correct either. The cactus spine would not only require the loss of cells, vascular tissue, etc., found in leaves, but would require specific genetic information to develop. The description above would be true for the basic plan of each cactus spine, but even cactus spines are wide ranging in their final forms, possibly requiring further specific information. As it requires the activation of specific genes at the correct time for the spine to form, this would indicate that it was indeed designed, possibly involving the activation of latent genetic information used in the formation of cactus spines being unmasked at the Fall. This would fit well with God, who is purposeful in everything that he does,[23] even when implementing the Curse, making the cactus spine's numerous obvious functions and its newly discovered function a design feature attributed to God's intricacy and creativeness.

submerged into a mixture of silicone oil and water that was blasted with ultrasonic sound waves to generate the micron-sized oil droplets. The team then observed that underwater oil droplets collect on and flow along the needles in a similar way that the water collects on and moves along the cactus spines. Testing different array set ups, the team found that an array with hexagonal grids of the silicone polymer needles proved to be the most effective, due to a higher density of needles, separating up to 99% of the oil from the water. This new technology, if it can replicate the same results in a genuine oil spill, could prove to be a very effective tool in cleanup operations.

## Origin of the cactus spine

This incredible feature of the cactus spine, inspiring new technology, was given the usual evolution lip service, with no explanation offered as to how it or the laws of physics that it utilizes may have arisen.

Very few cactus fossil specimens have ever been found,[15] meaning that, for the evolutionist, "the timing of cactus origins and diversification has remained enigmatic."[16] From a biblical perspective we know both the origin of the cactus spine and that of the fossils. Cactus spines are a reminder of the entrance of sin into the perfect world that God had created for man, and the subsequent Curse on creation detailed in Genesis 3.[17] The cactus fossil specimens formed from cactuses buried during Noah's Flood, the Flood judging mankind's wickedness, and being referred to by Jesus as both a real historical event and an example of his coming judgment.[18] Yet even in such a spiny reminder of our fall we see the evidence of God's great design, purpose, and providence.

## Conclusion

This new technology is only a copy of the real thing. The design feature and the laws of physics that it utilizes are a clear and powerful demonstration of the mind behind them, revealing the Creator God.

## References

1. A large accidental marine oil spill with a sea-floor oil gusher flowing for 87 days and discharging an estimated 760 million litres (200 million US gallons) of crude oil. Over 8,000 animals were reported dead due to the effects of the oil spill in the first 6 months.
2. Reading University, UK, Biomimetics department, home webpage definition of biomimetics; www.reading.ac.uk/biomimetics/about.htm, accessed 20 January 2014.
3. See creation.com/design-features-questions-and-answers for more examples.
4. Li, K. *et al*., Structured cone arrays for continuous and effective collection of micron-sized oil droplets from water, *Nat. Commun*. **4**:2276, 2013; doi: 10.1038/ncomms3276.
5. Ju, J. *et al.,* A multi-structural and multi-functional integrated fog collection system in cactus, *Nat. Commun*. **3**:1247, 2012; doi: 10.1038/ncomms2253.
6. Technically called glochids, which are very small barbed spines that are deciduous.
7. Ju *et al.,* ref. 5, p. 1.
8. Or the barb that it lands on.
9. The gradient of surface-free energy and gradient of Laplace pressure are believed to be the pri-mary driving forces behind these phenomena. The water droplet always moves towards the base of the spine regardless of the angle of the spine.
10. Batten, D., C4 photosynthesis—evolution or design? *J. Creation* **16**(2):13–15, 2002; endnote 2; creation.com/c4-photosynthesisevolution-or-design.
11. Li *et al*., ref. 4, p. 2.
12. The silicon-based organic polymer was Polydimethylsiloxane (PDMS).
13. Meaning that the materials have a strong affinity for oils rather than water.
14. Li, ref. *et al.,* 4, p. 5.
15. Chaney, R., A fossil cactus from the Eocene of Utah, *American J. Botany* **31**(8):507–528, 1944.
16. Arakaki, M. *et al*., Contemporaneous and recent radiations of the world's major succulent plant lineages, *PNAS* **108**(20):8379–8384, 2011.
17. "Because you listened to your wife and ate from the tree about which I commanded you, 'You must not eat of it', cursed is the ground because of you; through painful toil you will eat of it all the days of your life. It will produce thorns and thistles for you, and you will eat the plants of the field. By the sweat of your brow you will eat your food until you return to the ground, since from it you were taken; for dust you are and to dust you will return" (Genesis 3:17–19).
18. Matthew 24:37–44.
19. Catchpoole, D., A thorny issue, *Creation* **34**(3):52–55, July 2012*;* creation.com/a-thorny-issue.
20. Batten *et al., The Creation Answers Book*, chapter 6, How did bad things come about? creation.com/images/pdfs/cabook/chapter6.pdf
21. While these may appear to be a degenerative mutation due to their relative simplicity in formation compared to the cactus spines, it does not mean that they are, and it is highly likely that they were implemented by God as part of the Genesis 3 Curse.
22. Mauseth, J.D., Cactus Spines—The evolutionary conversion of leaves to spines in cacti, tinyurl.com/cactispine accessed 20 January 2014. James D. Mauseth is a Professor in the Department of Integrative Biology, College of Natural Sciences, The University of Texas at Austin.
23. Proverbs 16:4.