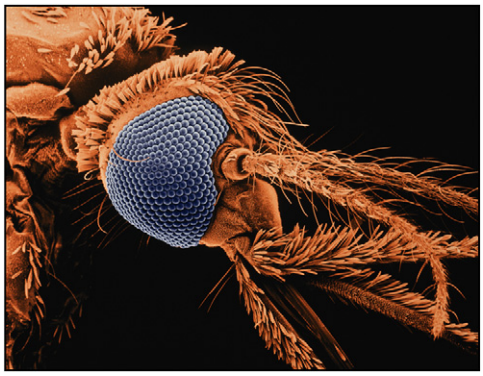
Cell Culture

Summer time is vacation time—a chance to step away from minipreps or grant deadlines and investigate nature outside the lab. For many of us, that means a trip to the beach. But don't let those colorful umbrellas and vigilant lifeguards fool you. Every foray into nature is ultimately a battle between predator and prey. In this Cell Culture, we explore cellular and molecular mechanisms used by predators at the beach to track us down and take a bite.

Mosquito Magnets



Mosquitoes have three olfactory appendages: the antenna, the proboscis, and the maxillary. Image by Tim Flach, Stone, Getty Images.

Whether you're tanning in Tahiti or lounging on Long Island, chances are you'll probably fall prey to at least a few mosquitoes this summer. Many of these micro-vampires happily feed on any warm-blooded animal. However, a recent study by Carey et al. (2010) suggests that *Anopheles gambiae* (the major transmitter of malaria) has evolved chemoreceptors specifically equipped to seek out humans. *A. gambiae* contains 79 genes encoding odor receptors in its olfactory neurons. To characterize the scents detected by these proteins, the authors engineered a mutant fruit fly lacking its endogenous odor receptors and expressed the mosquito genes in their place. Fifty of the mosquito receptors were functional and exhibited excitatory responses to an array of volatile compounds in the mutant fly. Surprisingly, more than 20 of the receptors reacted to compounds in human sweat. Three receptors were narrowly tuned and had high sensitivity to particular human scents, suggesting that they are specialist receptors evolved distinctively to locate humans. For example, the AgOr2 receptor responds with high sensitivity and high selectivity to a set of aromatic compounds that includes indole, which constitute nearly 30% of our "human scent." On the other hand, AgOr5 is selectively tuned to detect diacetyl, a metabolic byproduct of bacteria on your skin that has a buttery scent. The researchers are now using this system to identify compounds that "jam" the mosquitoes' receptors. Hopefully, this will facilitate the development of the perfect cocktail for repelling mosquitoes and combating the spread of malaria.

*Carey et al. (2010). Nature **464**, 66–71.*

Golgi-derived vesicles store the stinging spines of jellyfish. This photo is licensed from Flickr user Stacy Blackman (http://www.flickr.com/photos/stacyblackman/) under a Creative Commons Attribution license.

Golgi Guns

For beachgoers in southern California, mosquitoes may be the least of their concerns this summer. A rare species of giant purple jellyfish with 3-foot-wide domes and 30-foot-long tentacles is washing ashore on San Diego beaches. Although we think of jellyfish as having "stingers" like a wasp, jellyfish actually rely on ultra-fast exocytosis to unload their weapons on potential prey. Thus, the sting of a jellyfish is, in fact, more similar to neurotransmitter release at a synapse than to the stab of a wasp (Ozbek et al. 2009).

Mounted on the epithelial layer of their tentacles, the stinging cells of jellyfish called nematocytes contain a giant vesicle derived from the Golgi apparatus packed with venom and a spiny tubule coiled inside. When "dinner" rubs against the stinging cells, mechanosensory receptors generate an action potential, which then triggers the opening of calcium channels and exocytosis of the nematocyst vesicle. In less than 700 ns, the barbed end of the tubule shoots out of the nematocyte with accelerations greater 5 million *g* and pressures of up to 7 GPa (or ten times greater than that of a 9 mm rifle). Such large accelerations and pressures allow the tubule to puncture the cuticle of crustaceans or leave a nasty welt on your leg. What powers this nano-harpoon? Although the details are still unclear, a high concentration of poly-γ-glutamate molecules inside the vesicle generates an extremely large osmotic pressure, which probably drives release of the spiny tubule.

*Nutcher et al. (2006). Curr. Biol. **16**, R316–R318.*
*Ozbek et al. (2009). Toxicon **54**, 1038–1045.*

A great white shark near Cape Town, South Africa. This photo is licensed from Flickr user hermanusbackpackers (http://www.flickr.com/photos/hermanusbackpackers/) under a Creative Commons Attribution license.

Smelling in Stereo

Ocean swimmers in the northeastern US are on the lookout for a slightly more daunting predator than purple jellyfish. A great white shark was recently spotted lurking off the coast of Cape Cod hunting seals. Like other sharks, great whites track down seals by following columns or plumes of scents left behind as their victims swim. Recently, Gardiner and Atema (2010) showed that one shark species, *Mustelus cannis*, calculates the path of odor patches based on the difference in arrival times for when a scent reaches its two nostrils. In other words, the shark smells in stereo, extracting spatial information from temporal signals.

Previous studies had concluded that sharks, like many animals, track concentration gradients of odors. Looking to confirm this hypothesis, Gardiner and Atema fitted the sharks with headgear that dispenses squid-marinated liquid to each nostril with a 0.5 s time delay. Surprisingly, ~70% of the time, the shark turned in the direction of the nostril that first received the aroma, even when that side was given a lower concentration of odor. Thus, timing was more important than concentration for steering the shark into odor patches. Furthermore, Gardiner and Atema calculated that the greater the distance between the shark's nostrils, the faster the shark can swim and still keep contact with the scents. The authors speculate that this property may have contributed to the evolution of ''hammerhead'' sharks (*Sphyrna*) with widely separated nostrils on their flattened snouts.

This study is the first demonstrating that arrival times of odors can trump differences in concentration. However, many birds and mammals use a similar temporal strategy to localize the source of sounds. In humans, neurons in the brainstem act as ''coincident detectors'' that identify small differences (> 10 μs) in the arrival times of sound waves at each ear (Kuba et al. 2006). Remarkably, the morphology and subcellular properties of these neurons, such as the location of ion channels, are tuned to detect specific frequencies of sound. It will be interesting to determine whether stereo smelling is encoded by similar ''coincident detectors'' in the shark's brain.

*Kuba et al. (2006). Nature **444**, 1069–1072.*
*Gardiner and Atema (2010). Curr. Biol. **20**, 1187–1191.*

SpF 53

Although that giant star in the sky doesn't bite, its ultraviolet (UV) radiation can surely sting. Despite the unforgettable discomfort of a bad sunburn, many of us desire nothing more than to lie on the beach for hours, soaking up rays and browning our skin. In fact, multiple clinical studies find that almost half of all beach lovers may meet the psychiatric definition of ''addicted'' to sun tanning. What molecular mechanisms underlie this sun-seeking behavior?

Obviously, such complex human behaviors stem from multiple causes. However, a study by Cui et al. (2007) suggests that the tumor suppressor p53 orchestrates not only the golden glow of a fresh tan but also the relaxation and mood enhancement that often accompany it. The authors demonstrate that exposing mice to UV radiation at levels typical for a clear, summer day induces expression of the p53 protein, which in turn directly activates the transcription of the *pro-opiomelanocortin* (*POMC*) gene. POMC is the precursor for the hormone that stimulates production of melanin, the dark-brown polymer that gives your skin a tan. Interestingly, the same p53 pathway activated by UV light also induces the production of β-endorphin, another cleavage product of POMC. β-endorphin is an endogenous opioid with analgesic properties. Why would p53 trigger the production of such a pleasure-producing molecule? The authors speculate that β-endorphin may mitigate the discomfort triggered by local inflammation at the site of a sunburn, but further studies are needed to confirm this hypothesis.

*Cui et al. (2007). Cell **128**, 853–864.*

Michaeleen Doucleff