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Physiological consequences of evolution: Quantifying the costs of adaptive resistance to tetrodotoxin in gartersnakes

Measuring the physiological consequences of discrete evolutionary adaptations is a critical component to predicting ecological responses. While adaptations may be overall beneficial to an animal, there may be unknown costs. To adequately understand potential trade−offs associated with discrete physiological adaptations, we must measure the true costs of these adaptations. To accomplish this, we utilized a well−known model of co−evolution: the resistance of the natural toxin tetrodotoxin (TTX) by gartersnakes that are sympatric with TTX−secreting newts, a prey item. Gartersnakes that have evolved outside the range of these newts have not evolved this resistance, making a contrast between individuals with high and low resistance possible. We measured individual resistance to TTX in snakes from a resistant population from Benton County, OR and a non−resistant population from Cache County, UT by determining the dose that reduced racing speed by 50%. To assess the potential trade−offs involved with evolving this resistance, we determined the efficacy of the stress and immune responses in these individuals by quantifying corticosterone (CORT) and bactericidal ability. By correlating these important life−history functions to a measurable adaptation such as resistance to a natural toxin, we can better understand the role of physiological processes in evolution.

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3D surface−based morphometrics used to determine the intraspecific differences within the tail of syngnathid fishes

Seahorses and pipehorses both possess a prehensile tail, a unique characteristic among teleost fishes, allowing them to grasp and hold onto substrates, like sea grasses. Pipefishes, representing the ancestral condition, have a rather rigid tail. The tail of all these syngnathid fishes is characterized by a vertebral column that is surrounded with dermal plates − four per vertebra. The goal of this study is to determine the relation between the differences in plate and vertebral morphology and the flexibility of the tail. To do so, a 3D morphometrical analysis based on surface meshes generated based on µCT−scans was performed, followed by a PC analysis and a scree plot with broken stick analysis. Four different analyses were applied on the tail of nine different species (four pipehorses, two seahorses, one pipefish and one seadragon): (1) a comparison between the proximal and distal vertebrae, (2+3) a comparison between the proximal and distal ventral resp. dorsal plates and (4) a comparison between both the dorsal and ventral dermal plates. For the analysis on the vertebrae, the main differences could be found in the length and orientation of the parapophyses and the neural and hemal spines in all species, as well as the inclination angle of the vertebral body in species with a prehensile tail. The main difference between the proximal and distal dermal plates in prehensile tails is the overall shape of the plates, which changes from rectangular to square. The analysis comparing the ventral and dorsal dermal plates showed significant differences between both in all studied species. Overall, a higher intraspecific variation is observed in species with a prehensile tail.

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Increased movement compensates for noisy sensory acquisition

Many animal behaviors involve motion of the body or appendages for sensing the environment to gain information, which we term active sensing. As an example, weakly electric fish will sweep back and forth near a novel object to gain information. Using information theoretic approaches should help explain such movements in active sensing tasks that seem counterproductive. For instance, bats aim their sonar pulses off axis from a target, which decreases signal intensity but maximizes a common measure of information. However, in simulations of a mobile sensor tasked with tracking a target moving along a line, sensor motions that visit portions of the line proportional to the amount of expected information vastly outperform motions that constantly maximize information. The resulting simulated trajectories feature oscillations around the target in order to maintain a low variance estimate of object location. Moreover, as the signal to noise ratio (SNR) increases, these oscillations diminish and the sensor trajectories more closely match target motion. Electric fish (*E. virescens*) will follow the movements of a swaying shelter to remain hidden but also exhibit extraneous fore−aft and bending motions similar to when they are sensing a new object. This extra movement is more prevalent when visual cues are unavailable and SNR is low. Moreover, by further decreasing the SNR through conductivity increase or by applying a jamming signal (both shown to degrade electrosense), the fish increases the amplitude of the extra movements. These trends are consistent with the simulations of the target tracking task in various levels of noise. Using this information−theoretic approach might elucidate reasoning behind other non−intuitive animal behaviors and guide robotic algorithms for information gathering tasks to be more effective.

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Sinus hair sensing in forelimb positional control during the locomotion of rats (Rattus norvegicus, Rodentia)

Facial (mystacial) vibrissae, a kind of sinus hairs within the group of tactile hairs, have been intensively studied for muscle activities, neurological patterns, anatomy details and their biological role in different species. The skill to move in a more or less regular pattern (whisking) is known from various species, like rats. In addition to these whiskers rats have other sinus hairs, e.g. the non−moving carpal ones on the forelimbs. It has been assumed that carpal sinus hairs have a sensory function during locomotion on different substrates by detecting discontinuities while whiskers detect vertical obstacles. The possibility of a coupled sensorimotor control between the limbs and the sinus hairs might lead to a stabilized locomotion over uneven substrate. To test this hypothesis several spatiotemporal speed dependent parameters as well as kinematic data for the limbs were quantified and linked to the motion of carpal and facial sensors. Parameters were measured from x−ray and high−speed videos. A treadmill with continuous and discontinuous substrate was used. Rats had to walk under the presence and absence of the carpal and/or mystacial tactile hairs. Data were collected for a speed range of 0.2 to 0.5 m/s. Collecting tactile information by whiskers and carpal sinus hairs during touchdown and swing phase of the limbs is an important factor to get information about the substrate where the limb is going to be placed next. Loss of the sinus hairs affected the degree of parameter variation but not average parameters or the failure rate of the limbs during walking on the perforated treadmill. The motion of whiskers is affected by the presence/absence of the carpal sinus hairs and might compensate the loss of this substrate sensor.