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Predation Risk

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Introduction

Predation is one of the strongest evolutionary forces in the animal kingdom. The need to catch food influences the ecology, morphology, and behavior of predators and prey alike. As a consequence, predation risk has not only a stark effect on the single individual but further shapes food webs and whole ecosystems. Predator-prey interactions can be understood as an arms race: Over evolutionary time spans, predators developed a multitude of hunting strategies to catch prey, which in turn developed better and more sophisticated antipredator strategies. Such arms races are indeed the cause of many extraordinary color patterns and morphological features as well as fascinating behaviors observed in nature. In the following we will elucidate these diverse adaptions of predators and prey, followed by a short overview on the evolutionary consequences of predation risk on shaping complex social organizations of predators and prey at the same time.

Adaptations of Predators

Predators evolved multifarious morphological and behavioral adaptations that increase their chances to successfully hunt prey. Many predators are active hunters that search for prey animals. Once spotted, these prey items might be chased until they are caught. Such active hunters are characterized by well-developed muscles which support high-speed pursuits, excellent sensory capabilities, and a huge repertoire of stealth and stalking techniques. It is therefore not surprising that the fastest animals on land, water, and in the air are all highly specialized predators. The peregrine falcon (*Falco peregrinus*), for example, is the fastest animal alive, with a diving speed of up to 389 km/h. But predator's adaptations are not limited to increasing the attacker's speed. Nocturnal predators, such as the African wildcat (*Felis lybica*), have specialist eyesight and large pupils to see even the faintest light during darkness, while sharks are able to sense the electric field of other animals, allowing them to spot prey which is cryptic or hidden in the sand.

By contrast, ambush predators don't rely only on strength or speed; instead they hide and wait until prey is close enough before starting an attack. A common house cat sitting motionless in front of a mousehole is a prominent example of such hunting tactic. To reduce their visibility, many ambush predators, such as the cougar (*Puma concolor*) or the devil scorpionfish (*Inimicus filamentosus*), bear camouflage color

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patterns that allow them to stay unnoticed by prey until striking the attack. Orchid mantis (*Hymenopus coronatus*), for example, resemble orchid flowers in color. Insects that visit this apparent nectar source are attacked and killed. Ambush hunting is less energy-demanding than active searching for prey. However, the chance to meet a prey item is reduced. To increase such chances, some ambush hunters evolved morphological or behavioral features attracting prey animals, a phenomenon termed "aggressive mimicry" (Jamie 2017). For example, alligator snapping turtles possess a modified tongue, which resembles a worm. Hiding on the muddy bottom of a lake, they open their mouth and move their worm like tongue. Small fishes get attracted by this lure and swim directly into the mouth of the turtle. A further example is Livingston's cichlid fish (*Nimbochromis livingstonii*), a predator showing sophisticated adaptions in behavior and color. To attract its prey items, it feigns death and mimics a rotting fish. Other fishes that approach this potential snack are attacked and eaten. Finally, some ambush hunters like spiders or ant lions evolved sophisticated traps to catch bypassing prey.

Many predators like tigers, sharks, or birds of prey hunt alone. Such solitary hunting has the benefit that the catch does not have to be shared between several individuals. Furthermore, a single hunter is more difficult to be detected when approaching prey animals than a group of predators. However, compared to group hunting species, the success rate of solitary hunters is lower, and they often face difficulties to bring down large prey items. Such problems might be overcome if individuals gather together and hunt as a group (Davies et al. 2012). Indeed, group hunting evolved frequently throughout the animal kingdom, exemplified in packs of wolves or pods of killer whales. While many of such group hunting species did not evolve coordinated hunting strategies, others show highly coordinated behaviors. For example, lions (*Panthera leo*) form hunting coalitions that are more successful than single individual's hunting. Forming such hunting groups requires coordinated behaviors, advanced communication, and very often division of labor between group members. In such highly derived group hunting species, sharing the catch among group members is often based on social hierarchies, which are based on dominance ranks, age, or sex. Sharing the catch is usually neither fair nor equal. Thus, more dominant individuals are often more strongly benefitting from group hunting, while it might pay off for low-ranked individuals to hunt alone.

Adaptations of Prey

While a predator that is unsuccessful in capturing a prey item usually only loses a meal, a prey animal that fails parrying an attack will lose its life. Consequently, prey animals evolved a fascinating array of morphological, physiological, cognitive, and behavioral features, lowering their predation risk and increasing survival chances. Such antipredator adaptations can be categorized broadly into strategies to (1) avoid encountering and detection, (2) escape an attack, and (3) deter predators (Godin 1999).

Strategies to Avoid Encountering and Detection

Many prey animals avoid predators spatially or temporally. For example, in the presence of large fish predators, small fishes like guppies (Poecilia reticulata) might move to shallow parts of the pond or brook, as large predators are not able to follow them there. Other prey animals might switch their daily activity, hiding during the daytime and foraging during the night. Nocturnal migration to the water column by zooplankton is a fascinating example of such temporal avoidance of predators. However, if the possibilities to avoid predators in space or time are limited, alternative strategies to reduce the risk of being detected and identified as potential prey are needed. A straightforward strategy to reduce the risk of being detected is by seeking a shelter or by reducing body activity to a minimum until the risk is over. Indeed, some prey species reduce their heart rate to cease their activity and remain immobile when being approached by a predator. Detection risk might further be lowered through

camouflaging and masquerading. Here, prey coloration and/or morphology resembles the environmental background of the habitat or an uninteresting object such as leaves or twigs to increase the chances of staying unnoticed by predators (Ruxton et al. 2004). Such visual features might be permanent or highly flexible and readily adjusted to the respective environment. Leaf (Phylliidae) or stick insects (Phasmatodea) are prominent examples of permanent camouflage, whereas chameleons (Chamaeleonidae) and octopuses (Octopoda) use a flexible strategy to avoid predators by readily changing skin color to match the surrounding environment. In some cases, harmless and nontoxic species mimic other species that are better able to defend themselves or are poisonous. Harmless hoverflies (Syrphidae) resembling aggressive wasp and bee species (Batesian Hymenoptera) are famous examples for such mimicry (Ruxton et al. 2004).

Strategies to Escape an Attack

Once being detected by a predator, fleeing is the most common strategy of prey animals to avoid being eaten (Godin 1999). A successful flight by prey animals consists of an adequate timing to initiate the flight and a high-speed flight trajectory which leads into a safe area. Further, prey species relying on escape often show special adaptations. Many predator fish species, for example, are not able to ascend quickly in the water column, as their swim bladder will burst due to fast changes in pressure. However, physostomous fishes like herring, which are a common prey for many aquatic predators, possess an open swim bladder that is connected to their gut. These fishes can reduce pressure by excreting gas bubbles. This allows them to ascend quickly and thus escape predator attacks (Blaxter 1985).

To successfully escape an attack, it is important to spot the predator as soon as possible. Here, living in a group is highly beneficial. Groups detect predators faster than single individuals do, a phenomenon termed the *many eyes effect*. By joining forces, the overall vigilance time of a group might even increase without compromising time for other behaviors such as feeding and mating (Krause and Ruxton 2002). Furthermore, group living in itself is already a very effective antipredator strategy. Group-living species such as the gigantic flocks of snow geese and the herds of migrating wildebeest in the Serengeti are protected from predators because their sheer numbers confuse and repel predators which are not able to single out lone individuals. Finally, the dilution effect postulates that living in a group simply reduces the risk of each single individual to be the target of the predator (Krause and Ruxton 2002).

Strategies to Deter Predators

Prey can deter predators using defensive adaptions such as toxicity, spines, or defensive behaviors. Often, toxic prey species evolved signals that are associated with the unprofitability to potential predators. These bright and conspicuous warning colors have been coined “aposematism” (Ruxton et al. 2004). The tropical poison frogs (Dendrobatidae), for example, are brightly colored to advertise their toxicity to potential predators (Santos et al. 2003).

Many prey animals show aggressive defense behaviors toward the predator. These are especially effective in group-living species which defend the group jointly (Krause and Ruxton 2002). For example, pairs of crows will join together to chase away hawks from their breeding sites, and herds of buffalos will aggressively confront lions together.

Impact of Predation Risk on Higher Organizational Levels

Predation risk can shape whole populations either indirectly (as explained above in *Adaptions of prey*) or directly through the consumption of prey animals by predators. Direct predation has a negative effect on survival and longevity of individuals and therefore selects individuals which are able to avoid predation risk and thus pass their genes to the next generation. This has a major influence on the way how individuals within a species interact with each other, determining the social structure and mating system of whole populations. For example, predation risk mediates

the evolution of highly social societies where individuals cooperate with each other to raise their young (Groenewoud et al. 2016).

Predation risk also affects behaviors and survival of individuals which have not been directly exposed to predators but "inherited" information about predators from their parents. These so-called nongenetic parental effects are widespread in the animal kingdom and enable the transmission of information about local predation risk to the next generation. For example, the common water flea (*Daphnia pulex*) develops a thick amour as a protection from predators. Interestingly, offspring from mothers that experienced predators develop thicker amour irrespective of whether they have experienced predators themselves (Agrawal et al. 1999). In mammals and birds, predation risk as experienced by mothers can alter the stress responsiveness of offspring via maternal hormones through the milk in mammals or through hormones deposited inside eggs in birds (Sheriff and Love 2013).

Ultimately, reproductive barriers between species can be removed or created depending on predation risk. The ability of prey species to adapt to predators and to expand into habitats containing new predators greatly influences how successful species disperse and thus influences the potential for speciation to occur (Siepielski and Beaulieu 2017).

Conclusion

The constant struggle to survive is the major evolutionary force in the animal kingdom, leading to an arms race between predators and prey. Predation risk influences individual behaviors, population dynamics, and ultimately the evolution of animal social societies. Certainly, humans are not excluded from this struggle, and human sociality has been shaped just like any other animal sociality by the need to survive and catch food (Hart and Sussman 2008). Only by understanding the evolutionary forces shaped by the struggle to survive we are able to fully appreciate the development of the rich and interesting facets of animal behaviors and animal sociality.

Cross-References

- ▶ Aposematism
- ▶ Benefits of Group Living
- ▶ Cryptic Coloration
- ▶ Dominance Hierarchy
- ▶ Escape Response
- ▶ Mullerian mimicry
- ▶ Vigilance

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