

= Anti @-@ predator adaptation =

Anti @-@ predator adaptations are mechanisms developed through evolution that assist prey organisms in their constant struggle against predators . Throughout the animal kingdom , adaptations have evolved for every stage of this struggle .

The first line of defence consists in avoiding detection , through mechanisms such as camouflage , living underground , or nocturnality . Alternatively , prey animals may ward off attack , whether by advertising the presence of strong defences in aposematism , by mimicking animals which do possess such defences , by startling the attacker , by signalling to the predator that pursuit is not worthwhile , by distraction , by using defensive structures such as spines , and by living in a group . Members of groups are at reduced risk of predation , despite the increased conspicuousness of a group , through improved vigilance , predator confusion , and the likelihood that the predator will attack some other individual .

Some prey species are capable of fighting back against predators , whether with chemicals , through communal defence , or by ejecting noxious materials . Finally , some species are able to escape even when caught by sacrificing certain body parts : crabs can shed a claw , while lizards can shed their tails , often distracting predators long enough to permit the prey to escape .

= = Avoiding detection = =

= = = Staying out of sight = = =

Animals may avoid becoming prey by living out of sight of predators , whether in caves , underground , or by being nocturnal . Nocturnality is an animal behavior characterized by activity during the night and sleeping during the day . This is a behavioral form of crypsis that can be used by animals to either avoid predation or to enhance prey hunting . Predation risk has long been recognized as critical in shaping behavioral decisions . For example , this predation risk is of prime importance in determining the time of evening emergence in echolocating bats . Although early access during brighter times permits easier foraging , it also leads to a higher predation risk from bat hawks and bat falcons . This results in an optimum evening emergence time that is a compromise between the conflicting demands . Another nocturnal adaptation can be seen in kangaroo rats , which exhibit moonlight avoidance . These rodents forage in relatively open habitats and reduce their activity outside their nest burrows in response to moonlight . During a full moon , they shift their activity towards areas of relatively dense cover to compensate for the extra brightness . In controlled experiments , artificial moon @-@ like illumination stimulates similar responses in their foraging behavior , suggesting that this behavior has evolved to reduce predation risk .

= = = Camouflage = = =

Camouflage uses any combination of materials , coloration , or illumination for concealment to make the organism hard to detect by sight . It is common in both terrestrial and marine animals . Camouflage can be achieved in many different ways , such as through resemblance to surroundings , disruptive coloration , shadow elimination , self @-@ decoration , cryptic behavior , or changeable skin patterns and color . Animals such as the flat @-@ tail horned lizard of North America have evolved to eliminate their shadow and blend in with the ground . The bodies of these lizards are flattened , and their sides thin towards the edge . This body form , along with the white scales fringed along their sides , allows the lizards to effectively hide their shadows . Additionally , these lizards hide any remaining shadows by pressing their bodies to the ground .

= = Warding off attack = =

Many species make use of behavioral strategies to deter predators .

=== Startling the predator ===

Many animals , including moths , butterflies , mantises , phasmids , and cephalopods such as octopuses , make use of patterns of threatening or startling behaviour , such as suddenly displaying conspicuous eyespots , so as to scare off or momentarily distract a predator , thus giving the prey animal an opportunity to escape .

=== Pursuit @-@ deterrent signals ===

Pursuit @-@ deterrent signals are behavioral signals used by prey that convince predators not to pursue them . For example , gazelles stot , jumping high with stiff legs and an arched back . This is thought to signal to predators that they have a high level of fitness and can outrun the predator . As a result , predators may choose to pursue a different prey that is less likely to outrun them . Warning calls given by birds such as the Eurasian jay are similarly honest signals , benefiting both predator and prey : the predator is informed that it has been detected and might as well save time and energy by giving up the chase , while the prey is protected from attack .

=== Playing dead ===

Another pursuit @-@ deterrent signal is thanatosis or playing dead . Thanatosis is a form of bluff in which an animal mimics its own dead body , feigning death to avoid being attacked by predators seeking live prey . Thanatosis can also be used by the predator in order to lure prey into approaching . An example of this is seen in white @-@ tailed deer fawns , which experience a drop in heart rate in response to approaching predators . This response , referred to as " alarm bradycardia " , causes the fawn 's heart rate to drop from 155 to 38 beats per minute within one beat of the heart . This drop in heart rate can last up to two minutes , causing the fawn to experience a depressed breathing rate and decrease in movement , called tonic immobility . Tonic immobility is a reflex response that causes the fawn to enter a low body position that simulates the position of a dead corpse . Upon discovery of the fawn , the predator loses interest in the " dead " prey . Additionally , other symptoms of alarm bradycardia , including salivation , urination , and defecation , can cause the predator to lose interest .

=== Distraction ===

Marine molluscs such as sea hares , cuttlefish , squid and octopuses give themselves a last chance to escape by distracting their attackers . To do this , they eject a mixture of chemicals , which may mimic food or otherwise confuse predators . In response to a predator , animals in these groups release ink , creating a cloud , and opaline , affecting the predator 's feeding senses , causing it to attack the cloud .

Distraction displays attract the attention of predators away from an object , typically the nest or young , that is being protected . Distraction displays are performed by some species of birds , which may feign a broken wing while hopping about on the ground , and by some species of fish .

=== Mimicry and aposematism ===

Mimicry occurs when an organism (the mimic) simulates signal properties of another organism (the model) to confuse a third organism . This results in the mimic gaining protection , food , and mating advantages . There are two classical types of defensive mimicry : Batesian and Müllerian . Both involve aposematic coloration , or warning signals , to avoid being attacked by a predator .

In Batesian mimicry , a palatable , harmless prey species mimics the appearance of another species that is noxious to predators , thus reducing the mimic 's risk of attack . This form of mimicry is seen in many insects . The idea behind Batesian mimicry is that predators that have tried to eat

the unpalatable species learn to associate its colors and markings with an unpleasant taste . This results in the predator learning to avoid species displaying similar colors and markings , including Batesian mimics . Some species of octopus can mimic a selection of other animals by changing their skin color , skin pattern and body motion . When a damselfish attacks an octopus , the octopus mimics a banded sea @-@ snake . The model chosen varies with the octopus 's predator and habitat . Most of these octopuses use Batesian mimicry , selecting an organism repulsive to predators as a model .

In Müllerian mimicry , two or more aposematic forms share the same warning signals , as in viceroy and monarch butterflies . Birds avoid eating both species because their wing patterns honestly signal their unpleasant taste .

== Defensive structures ==

A spine is a sharp , needle @-@ like structure used to inflict pain on predators . An example of this seen in nature is in the Sohal surgeonfish . These fish have a sharp scalpel @-@ like spine on the front of each of their tail fins , able to inflict deep wounds . The area around the spines is often brightly colored to advertise the defensive capability ; predators often avoid the Sohal surgeonfish . Defensive spines may be detachable , barbed or poisonous . Porcupine spines are long , stiff , break at the tip , and are barbed to stick into a would @-@ be predator . In contrast , the hedgehog 's short spines , which are modified hairs , readily bend , and are barbed into the body , so they are not easily lost ; they may be jabbed at an attacker .

Many species of slug caterpillar , Limacodidae , have numerous protuberances and stinging spines along their dorsal surfaces . Species that possess these stinging spines suffer less predation than larvae that lack them , and a predator , the paper wasp , chooses larvae without spines when given a choice .

== Safety in numbers ==

Group living can decrease the risk of predation to the individual in a variety of ways , as described below .

== Dilution effect ==

A dilution effect is seen when animals living in a group " dilute " their risk of attack , each individual being just one of many in the group . George C. Williams and W.D. Hamilton proposed that group living evolved because it provides benefits to the individual rather than to the group as a whole , which becomes more conspicuous as it becomes larger . One common example is the shoaling of fish . Experiments provide direct evidence for the decrease in individual attack rate seen with group living , for example in Camargue horses in Southern France . The horse @-@ fly often attacks these horses , sucking blood and carrying diseases . When the flies are most numerous , the horses gather in large groups , and individuals are indeed attacked less frequently . Water striders are insects that live on the surface of fresh water , and are attacked from beneath by predatory fish . Experiments varying the group size of the water striders showed that the attack rate per individual water strider decreases as group size increases .

== Selfish herd ==

The selfish herd theory was proposed by W.D. Hamilton to explain why animals seek central positions in a group . It refers to the idea of reducing the individual 's domain of danger . A domain of danger is the area within the group in which the individual is more likely to be attacked by a predator . The center of the group has the lowest domain of danger , so animals will constantly strive to gain this position . In a study testing Hamilton 's selfish herd effect , Alta De Vos and Justin O 'Rainn (2010) studied brown fur seal predation from great white sharks . Using decoy seals , the

researchers varied the distance between the decoys to produce different domains of danger . The seals with a greater domain of danger had an increased risk of shark attack .

= = = Predator satiation = = =

A radical strategy for avoiding predators which may otherwise kill a large majority of the emerging young of a population is to emerge very rarely , at irregular intervals . This strategy is seen in dramatic form in the periodical cicadas , which emerge at intervals of 13 or 17 years . Predators with a life @-@ cycle of one or a few years are unable to reproduce rapidly enough in response to such an emergence , so predator satiation is a likely evolutionary explanation for the cicadas ' unusual life @-@ cycle . Predators may still feast on the emerging cicadas , but are unable to consume more than a fraction of the brief surfeit of prey .

= = = Alarm calls = = =

Animals that live in groups often give alarm calls that give warning of an attack . For example , vervet monkeys give different calls depending on the nature of the attack : for an eagle , a disyllabic cough ; for a leopard or other cat , a loud bark ; for a python or other snake , a " chatter " . The monkeys hearing these calls respond defensively , but differently in each case : to the eagle call , they look up and run into cover ; to the leopard call , they run up into the trees ; to the snake call , they stand on two legs and look around for snakes , and on seeing the snake , they sometimes mob it . Similar calls are found in other species of monkey , while birds also give different calls that elicit different responses .

= = = Improved vigilance = = =

In the improved vigilance effect , groups are able to detect predators sooner than solitary individuals . For many predators , success depends on surprise . If the prey is alerted early in an attack , they have an improved chance of escape . For example , wood pigeon flocks are preyed upon by goshawks . Goshawks are less successful when attacking larger flocks of wood pigeons than they are when attacking smaller flocks . This is because the larger the flock size , the more likely it is that one bird will notice the hawk sooner and fly away . Once one pigeon flies off in alarm , the rest of the pigeons follow . Wild ostriches in Tsavo National Park in Kenya feed either alone or in groups of up to four birds . They are subject to predation by lions . As the ostrich group size increases , the frequency at which each individual raises its head to look for predators decreases . Because ostriches are able to run at speeds that exceed those of lions for great distances , lions try to attack an ostrich when its head is down . By grouping , the ostriches present the lions with greater difficulty in determining how long the ostriches ' heads stay down . Thus , although individual vigilance decreases , the overall vigilance of the group increases .

= = = Predator confusion = = =

Individuals living in large groups may be safer from attack because the predator may be confused by the large group size . As the group moves , the predator has greater difficulty targeting an individual prey animal . The zebra has been suggested by the zoologist Martin Stevens and his colleagues as an example of this . When stationary , a single zebra stands out because of its large size . To reduce the risk of attack , zebras often travel in herds . The striped patterns of all the zebras in the herd may confuse the predator , making it harder for the predator to focus in on an individual zebra . Furthermore , when moving rapidly , the zebra stripes create a confusing , flickering motion dazzle effect in the eye of the predator .

= = Fighting back = =

Defensive structures such as spines may be used both to ward off attack as already mentioned , and if need be to fight back against a predator . Methods of fighting back include chemical defences , mobbing , defensive regurgitation , and suicidal altruism .

= = = Chemical defences = = =

Many animals make use of poisonous chemicals for self @-@ defence . These may be concentrated in surface structures such as spines or glands , giving an attacker a taste of the chemicals before it actually bites or swallows the prey animal : many toxins are bitter @-@ tasting . A last @-@ ditch defence is for the animal 's flesh itself to be toxic , as in the puffer fish , danaid butterflies and burnet moths . Many insects acquire toxins from their food plants ; *Danaus* caterpillars accumulate toxic cardenolides from milkweeds (*Asclepiadaceae*) . The bombardier beetle has specialized glands on the tip of its abdomen that allows it to direct a toxic spray towards predators . The spray is generated explosively through oxidation of hydroquinones and is sprayed at a temperature of 100 ° C. Armoured crickets similarly release blood at their joints when threatened (autohaemorrhaging) . Several species of grasshopper including *Poecilocerus pictus* , *Parasanaa donovani* , *Aularches miliaris* , and *Tegra novaehollandiae* secrete noxious liquids when threatened , sometimes ejecting these forcefully . Spitting cobras squirt venom from their fangs when threatened ; it can blind a predator if it strikes the eye .

A few vertebrate species such as the Texas horned lizard are able to shoot squirts of blood from their eyes , by rapidly increasing the blood pressure within the eye sockets , if threatened . Because an individual may lose up to 53 % of blood in a single squirt , this is only used against persistent predators like foxes , wolves and coyotes (*Canidae*) , as a last defence . Canids often drop horned lizards after being squirted , and attempt to wipe or shake the blood out of their mouths , suggesting that the fluid has a foul taste ; they choose other lizards if given the choice , suggesting a learned aversion towards horned lizards as prey .

The slime glands along the body of the hagfish secrete enormous amounts of mucus when it is provoked or stressed . The gelatinous slime has dramatic effects on the flow and viscosity of water , rapidly clogging the gills of any fish that attempt to capture hagfish ; predators typically release the hagfish within seconds (pictured above) . Common predators of hagfish include seabirds , pinnipeds and cetaceans , but few fish , suggesting that predatory fish avoid hagfish as prey .

= = = Communal defence = = =

In communal defence , prey groups actively defend themselves by attacking or mobbing a predator , rather than allowing themselves to be passive victims of predation . Mobbing is the harassing of a predator by many prey animals . Mobbing is usually done to protect the young in social colonies . For example , red colobus monkeys exhibit mobbing when threatened by chimpanzees , a common predator . The male red colobus monkeys group together and place themselves between predators and the group 's females and juveniles . The males jump together and actively bite the chimpanzees . Fieldfares are birds which may nest either solitarily or in colonies . Within colonies , fieldfares mob and defecate on approaching predators , shown experimentally to reduce predation levels .

= = = Defensive regurgitation = = =

Some birds and insects use defensive regurgitation to ward off predators . The northern fulmar vomits a bright orange , oily substance called stomach oil when threatened . The stomach oil is made from their aquatic diets . It causes the predator 's feathers to mat , leading to the loss of flying ability and the loss of water repellency . This is especially dangerous for aquatic birds because their water repellent feathers protect them from hypothermia when diving for food .

European roller chicks vomit a bright orange , foul smelling liquid when they sense danger . This repels prospective predators and may alert their parents to danger : they respond by delaying their return .

Numerous insects utilize defensive regurgitation . The eastern tent caterpillar regurgitates a droplet of digestive fluid to repel attacking ants . Similarly , larvae of the noctuid moth regurgitate when disturbed by ants . The vomit of noctuid moths has repellent and irritant properties that help to deter predator attacks .

= = = Suicidal altruism = = =

An unusual type of predator deterrence is observed in the Malaysian exploding ant . Social hymenoptera rely on altruism to protect the entire colony , so the self @-@ destructive acts benefit all individuals in the colony . When a worker ant 's leg is grasped , it suicidally expels the contents of its hypertrophied glands , expelling corrosive irritant compounds and adhesives onto the predator . These prevent predation and serve as a signal to other enemy ants to stop predation of the rest of the colony .

= = Escaping = =

= = = Flight = = =

The normal reaction of a prey animal to an attacking predator is to flee by any available means , whether flying , gliding , falling , swimming , running or jumping according to the animal 's capabilities . Escape paths are often erratic , making it difficult for the predator to predict which way the prey will go next : for example , birds such as snipe , ptarmigan and black @-@ headed gulls evade fast raptors such as peregrine falcons with zigzagging or jinking flight . In the tropical rain forests of Southeast Asia in particular , many vertebrates escape predators by falling and gliding . Among the insects , many moths turn sharply , fall , or perform a powered dive in response to the sonar clicks of bats . Among fish , the stickleback follows a zigzagging path , often doubling back erratically , when chased by a fish @-@ eating merganser duck .

= = = Autotomy = = =

Some animals are capable of autotomy (self @-@ amputation) , shedding one of their own appendages in a last @-@ ditch attempt to elude a predator 's grasp or to distract the predator and thereby allow escape . The lost body part may be regenerated later . Certain sea slugs discard stinging papillae ; arthropods such as crabs can sacrifice a claw , which can be regrown over several successive moults ; among vertebrates , many geckos and other lizards shed their tails when attacked : the tail goes on writhing for a while , distracting the predator , and giving the lizard time to escape ; a smaller tail slowly regrows .