= Camouflage =

Camouflage is the use of any combination of materials , coloration , or illumination for concealment , either by making animals or objects hard to see (crypsis) , or by disguising them as something else (mimesis) . Examples include the leopard 's spotted coat , the battledress of a modern soldier , and the leaf @-@ mimic katydid 's wings . A third approach , motion dazzle , confuses the observer with a conspicuous pattern , making the object visible but momentarily harder to locate . The majority of camouflage methods aim for crypsis , often through a general resemblance to the background , high contrast disruptive coloration , eliminating shadow , and countershading . In the open ocean , where there is no background , the principal methods of camouflage are transparency , silvering , and countershading , while the ability to produce light is among other things used for counter @-@ illumination on the undersides of cephalopods such as squid . Some animals , such as chameleons and octopuses , are capable of actively changing their skin pattern and colours , whether for camouflage or for signalling .

Military camouflage was spurred by the increasing range and accuracy of firearms in the 19th century . In particular the replacement of the inaccurate musket with the rifle made personal concealment in battle a survival skill . In the 20th century , military camouflage developed rapidly , especially during the First World War . On land , artists such as André Mare designed camouflage schemes and observation posts disguised as trees . At sea , merchant ships and troop carriers were painted in dazzle patterns that were highly visible , but designed to confuse enemy submarines as to the target 's speed , range , and heading . During and after the Second World War , a variety of camouflage schemes were used for aircraft and for ground vehicles in different theatres of war . The use of radar since the mid @-@ 20th century has largely made camouflage for fixed @-@ wing military aircraft obsolete .

Non @-@ military use of camouflage includes making cell telephone towers less obtrusive and helping hunters to approach wary game animals . Patterns derived from military camouflage are frequently used in fashion clothing , exploiting their strong designs and sometimes their symbolism . Camouflage themes recur in modern art , and both figuratively and literally in science fiction and works of literature .

= = History = =

= = = In zoology = = =

In ancient Greece , Aristotle (384 BC ? 322 BC) commented on the colour @-@ changing abilities , both for camouflage and for signalling , of cephalopods including the octopus , in his Historia animalium :

The octopus ... seeks its prey by so changing its colour as to render it like the colour of the stones adjacent to it ; it does so also when alarmed .

Camouflage has been a topic of interest and research in zoology for well over a century . According to Charles Darwin 's 1859 theory of natural selection , features such as camouflage evolved by providing individual animals with a reproductive advantage , enabling them to leave more offspring , on average , than other members of the same species . In his Origin of Species , Darwin wrote :

When we see leaf @-@ eating insects green , and bark @-@ feeders mottled @-@ grey ; the alpine ptarmigan white in winter , the red @-@ grouse the colour of heather , and the black @-@ grouse that of peaty earth , we must believe that these tints are of service to these birds and insects in preserving them from danger . Grouse , if not destroyed at some period of their lives , would increase in countless numbers ; they are known to suffer largely from birds of prey ; and hawks are guided by eyesight to their prey , so much so , that on parts of the Continent persons are warned not to keep white pigeons , as being the most liable to destruction . Hence I can see no reason to doubt that natural selection might be most effective in giving the proper colour to each kind of grouse , and in keeping that colour , when once acquired , true and constant .

The English zoologist Edward Bagnall Poulton studied animal coloration , especially camouflage . In his 1890 book The Colours of Animals , he classified different types such as " special protective resemblance " (where an animal looks like another object) , or " general aggressive resemblance " (where a predator blends in with the background , enabling it to approach prey) . His experiments showed that swallowtailed moth pupae were camouflaged to match the backgrounds on which they were reared as larvae . Poulton 's " general protective resemblance " was at that time considered to be the main method of camouflage , as when Frank Evers Beddard wrote in 1892 that " tree @-@ frequenting animals are often green in colour . Among vertebrates numerous species of parrots , iguanas , tree @-@ frogs , and the green tree @-@ snake are examples " . Beddard did however briefly mention other methods , including the " alluring coloration " of the flower mantis and the possibility of a different mechanism in the orange tip butterfly . He wrote that " the scattered green spots upon the under surface of the wings might have been intended for a rough sketch of the small flowerets of the plant [an umbellifer] , so close is their mutual resemblance . " He also explained the coloration of sea fish such as the mackerel : " Among pelagic fish it is common to find the upper surface dark @-@ coloured and the lower surface white , so that the animal is inconspicuous when seen either from above or below . "

The artist Abbott Handerson Thayer formulated what is sometimes called Thayer 's Law , the principle of countershading . However , he overstated the case in the 1909 book Concealing @-@ Coloration in the Animal Kingdom , arguing that " All patterns and colors whatsoever of all animals that ever preyed or are preyed on are under certain normal circumstances obliterative " (that is , cryptic camouflage) , and that " Not one ' mimicry ' mark , not one ' warning color ' ... nor any ' sexually selected ' color , exists anywhere in the world where there is not every reason to believe it the very best conceivable device for the concealment of its wearer " , and using paintings such as Peacock in the Woods (1907) to reinforce his argument . Thayer was roundly mocked for these views by critics including Teddy Roosevelt .

The English zoologist Hugh Cott 's 1940 book Adaptive Coloration in Animals corrected Thayer 's errors , sometimes sharply : " Thus we find Thayer straining the theory to a fantastic extreme in an endeavour to make it cover almost every type of coloration in the animal kingdom . " Cott built on Thayer 's discoveries , developing a comprehensive view of camouflage based on " maximum disruptive contrast " , countershading and hundreds of examples . The book explained how disruptive camouflage worked , using streaks of boldly contrasting colour , paradoxically making objects less visible by breaking up their outlines . While Cott was more systematic and balanced in his view than Thayer , and did include some experimental evidence on the effectiveness of camouflage , his 500 @-@ page textbook was , like Thayer 's , mainly a natural history narrative which illustrated theories with examples .

Camouflage is a soft @-@ tissue feature that is rarely preserved in the fossil record , but rare fossilised skin samples from the Cretaceous period show that some marine reptiles were countershaded . The skins , pigmented with dark @-@ coloured eumelanin , reveal that both leatherback turtles and mosasaurs had dark backs and light bellies .

= = = Military = = =

= = = = Before 1800 = = = =

Ship camouflage was occasionally used in ancient times . Philostratus (c . 172 ? 250 AD) wrote in his Imagines that Mediterranean pirate ships could be painted blue @-@ gray for concealment . Vegetius (c . 360 ? 400 AD) says that " Venetian blue " (sea green) was used in the Gallic Wars , when Julius Caesar sent his speculatoria navigia (reconnaissance boats) to gather intelligence along the coast of Britain . The ships were painted entirely in bluish @-@ green wax , with sails , ropes and crew the same colour . There is little evidence of military use of camouflage on land before 1800 , but two unusual ceramics show men in Peru 's Mochica culture from before 500 AD , hunting birds with blowpipes which are fitted with a kind of shield near the mouth , perhaps to

conceal the hunters ' hands and faces . Another early source is a 15th @-@ century French manuscript , The Hunting Book of Gaston Phebus , showing a horse pulling a cart which contains a hunter armed with a crossbow under a cover of branches , perhaps serving as a hide for shooting game . Jamaican Maroons are said to have used plant materials as camouflage in the First Maroon War (c . 1655 ? 1740) .

= = = = 19th @-@ century origins = = = =

The development of military camouflage was driven by the increasing range and accuracy of infantry firearms in the 19th century . In particular the replacement of the inaccurate musket with weapons such as the Baker rifle made personal concealment in battle essential . Two Napoleonic War skirmishing units of the British Army , the 95th Rifle Regiment and the 60th Rifle Regiment , were the first to adopt camouflage in the form of a rifle green jacket , while the Line regiments continued to wear scarlet tunics . A contemporary study in 1800 by the English artist and soldier Charles Hamilton Smith provided evidence that grey uniforms were less visible than green ones at a range of 150 yards .

In the American Civil War , rifle units such as the 1st United States Sharp Shooters (in the Federal army) similarly wore green jackets while other units wore more conspicuous colours . The first British Army unit to adopt khaki uniforms was the Corps of Guides at Peshawar , when Sir Harry Lumsden and his second in command , William Hodson introduced a " drab " uniform in 1848 . Hodson wrote that it would be more appropriate for the hot climate , and help make his troops " invisible in a land of dust " . Later they improvised by dyeing cloth locally . Other regiments in India soon adopted the khaki uniform , and by 1896 khaki drill uniform was used everywhere outside Europe ; by the Second Boer War six years later it was used throughout the British Army .

= = = = First World War = = = =

In the First World War , the French army formed a camouflage corps , led by Lucien @-@ Victor Guirand de Scévola , employing artists known as camoufleurs to create schemes such as tree observation posts and covers for guns . Other armies soon followed them . The term camouflage probably comes from camoufler , a Parisian slang term meaning to disguise , and may have been influenced by camouflet , a French term meaning smoke blown in someone 's face . The English zoologist John Graham Kerr , artist Solomon J. Solomon and the American artist Abbott Thayer led attempts to introduce scientific principles of countershading and disruptive patterning into military camouflage , with limited success .

Ship camouflage was introduced in the early 20th century as the range of naval guns increased , with ships painted grey all over . In April 1917 , when German U @-@ boats were sinking many British ships with torpedoes , the marine artist Norman Wilkinson devised dazzle camouflage , which paradoxically made ships more visible but harder to target . In Wilkinson 's own words , dazzle was designed " not for low visibility , but in such a way as to break up her form and thus confuse a submarine officer as to the course on which she was heading " .

= = = = Second World War = = = =

In the Second World War , the zoologist Hugh Cott , a protégé of Kerr , worked to persuade the British army to use more effective camouflage techniques , including countershading , but , like Kerr and Thayer in the First World War , with limited success . For example , he painted two rail @-@ mounted coastal guns , one in conventional style , one countershaded . In aerial photographs , the countershaded gun was essentially invisible . The power of aerial observation and attack led every warring nation to camouflage targets of all types . The Soviet Union 's Red Army created the comprehensive doctrine of Maskirovka for military deception , including the use of camouflage . For example , during the Battle of Kursk , General Katukov , the commander of the Soviet 1st Tank Army , remarked that the enemy " did not suspect that our well @-@ camouflaged tanks were

waiting for him . As we later learned from prisoners , we had managed to move our tanks forward unnoticed " . The tanks were concealed in previously prepared defensive emplacements , with only their turrets above ground level . In the air , Second World War fighters were often painted in ground colours above and sky colours below , attempting two different camouflage schemes for observers above and below . Bombers and night fighters were often black , while maritime reconnaissance planes were usually white , to avoid appearing as dark shapes against the sky . For ships , dazzle camouflage was mainly replaced with plain grey in the Second World War , though experimentation with colour schemes continued .

As in the First World War , artists were pressed into service ; for example , the surrealist painter Roland Penrose became a lecturer at the newly founded Camouflage Development and Training Centre at Farnham Castle , writing the practical Home Guard Manual of Camouflage . The film @-@ maker Geoffrey Barkas ran the Middle East Command Camouflage Directorate during the 1941 ? 1942 war in the Western Desert , including the successful deception of Operation Bertram . Hugh Cott was chief instructor ; the artist camouflage officers , who called themselves camoufleurs , included Steven Sykes and Tony Ayrton . In Australia , artists were also prominent in the Sydney Camouflage Group , formed under the chairmanship of Professor William John Dakin , a zoologist from Sydney University . Max Dupain , Sydney Ure Smith and William Dobell were among the members of the group , which worked at Bankstown Airport , RAAF Base Richmond and Garden Island Dockyard .

= = = = After 1945 = = = =

Camouflage has been used to protect military equipment such as vehicles , guns , ships , aircraft and buildings as well as individual soldiers and their positions . Vehicle camouflage techniques begin with paint , which offers at best only limited effectiveness . Other methods for stationary land vehicles include covering with improvised materials such as blankets and vegetation , and erecting nets , screens and soft covers which may suitably reflect , scatter or absorb near infrared and radar waves . Some military textiles and vehicle camouflage paints also reflect infrared to help provide concealment from night vision devices . After the Second World War , radar made camouflage generally less effective , though coastal boats are sometimes painted like land vehicles . Aircraft camouflage too came to be seen as less important because of radar , and aircraft of different air forces , such as the Royal Air Force 's Lightning , were often uncamouflaged .

Many camouflaged textile patterns have been developed to suit the need to match combat clothing to different kinds of terrain (such as woodland , snow , and desert) . The design of a pattern effective in all terrains has proved elusive . The American Universal Camouflage Pattern of 2004 attempted to suit all environments , but was withdrawn after a few years of service . Terrain @-@ specific patterns have sometimes been developed but are ineffective in other terrains . The problem of making a pattern that works at different ranges has been solved with pixellated shapes , often designed digitally , that provide a fractal @-@ like range of patch sizes so they appear disruptively coloured both at close range and at a distance . The first genuinely digital camouflage pattern was the Canadian CADPAT , issued to the army in 2002 , soon followed by the American MARPAT . A pixellated appearance is not essential for this effect , though it is simpler to design and to print .

= = Principles = =

Camouflage can be achieved by different methods , described below . Most of the methods contribute to crypsis , helping to hide against a background ; but mimesis and motion dazzle protect without hiding . Methods may be applied on their own or in combination .

= = = Crypsis = = =

Crypsis means making the animal or military equipment hard to see (or to detect in other ways , such as by sound or scent) . Visual crypsis can be achieved in many different ways , such as by

living underground or by being active only at night , as well as by a variety of methods of camouflage .

= = = = Resemblance to the surroundings = = = =

Some animals ' colours and patterns resemble a particular natural background . This is an important component of camouflage in all environments . For instance , tree @-@ dwelling parakeets are mainly green ; woodcocks of the forest floor are brown and speckled ; reedbed bitterns are streaked brown and buff ; in each case the animal 's coloration matches the hues of its habitat . Similarly , desert animals are almost all desert coloured in tones of sand , buff , ochre , and brownish grey , whether they are mammals like the gerbil or fennec fox , birds such as the desert lark or sandgrouse , or reptiles like the skink or horned viper . Military uniforms , too , generally resemble their backgrounds ; for example khaki uniforms are a muddy or dusty colour , originally chosen for service in South Asia . Many moths show industrial melanism , including the peppered moth which has coloration that blends in with tree bark . The coloration of these insects evolved between 1860 and 1940 to match the changing colour of the tree trunks on which they rest , from pale and mottled to almost black in polluted areas . This is taken by zoologists as evidence that camouflage is influenced by natural selection , as well as demonstrating that it changes where necessary to resemble the local background .

= = = = Disruptive coloration = = = =

Disruptive patterns use strongly contrasting , non @-@ repeating markings such as spots or stripes to break up the outlines of an animal or military vehicle , or to conceal telltale features , especially the eyes , as in the common frog . Disruptive patterns may use more than one method to defeat visual systems such as edge detection . Predators like the leopard use disruptive camouflage to help them approach prey , while potential prey like the Egyptian nightjar use it to avoid detection by predators . Disruptive patterning is common in military usage , both for uniforms and for military vehicles . Disruptive patterning , however , does not always achieve crypsis on its own , as an animal or a military target may be given away by factors like shape , shine , and shadow .

The presence of bold skin markings does not in itself prove that an animal relies on camouflage , as that depends on its behaviour . For example , although giraffes have a high contrast pattern that could be disruptive coloration , the adults are extremely conspicuous when in the open . Some authors have argued that adult giraffes are cryptic , since when standing among trees and bushes they are hard to see at even a few metres ' distance . However , adult giraffes move about to gain the best view of an approaching predator , relying on their size and ability to defend themselves , even from lions , rather than on camouflage . A different explanation is implied by the fact that young giraffes are far more vulnerable to predation than adults : more than half of all giraffe calves die within a year , and giraffe mothers hide their calves , which spend much of the time lying down in cover while their mothers are away feeding . Since the presence of a mother nearby does not affect survival , it is argued that young giraffes must be extremely well camouflaged ; this is supported by the fact that coat markings are strongly inherited .

= = = = Eliminating shadow = = = =

Some animals , such as the horned lizards of North America , have evolved elaborate measures to eliminate shadow . Their bodies are flattened , with the sides thinning to an edge ; the animals habitually press their bodies to the ground ; and their sides are fringed with white scales which effectively hide and disrupt any remaining areas of shadow there may be under the edge of the body . The theory that the body shape of the horned lizards which live in open desert is adapted to minimise shadow is supported by the one species which lacks fringe scales , the roundtail horned lizard , which lives in rocky areas and resembles a rock . When this species is threatened , it makes itself look as much like a rock as possible by curving its back , emphasizing its three @-@

dimensional shape . Some species of butterflies , such as the speckled wood , Pararge aegeria , minimise their shadows when perched by closing the wings over their backs , aligning their bodies with the sun , and tilting to one side towards the sun , so that the shadow becomes a thin inconspicuous line rather than a broad patch . Similarly , some ground @-@ nesting birds including the European nightjar select a resting position facing the sun . The elimination of shadow was identified as a principle of military camouflage during the Second World War .

= = = = Self @-@ decoration = = = =

Some animals actively seek to hide by decorating themselves with materials such as twigs , sand , or pieces of shell from their environment , to break up their outlines , to conceal the features of their bodies , and to match their backgrounds . For example , a caddis fly larva builds a decorated case and lives almost entirely inside it ; a decorator crab covers its back with seaweed , sponges and stones . The nymph of the predatory masked bug uses its hind legs and a ' tarsal fan ' to decorate its body with sand or dust . There are two layers of bristles (trichomes) over the body . On these , the nymph spreads an inner layer of fine particles and an outer layer of coarser particles . The camouflage may conceal the bug from both predators and prey .

Similar principles can be applied for military purposes , for instance when a sniper wears a ghillie suit designed to be further camouflaged by decoration with materials such as tufts of grass from the sniper 's immediate environment . Such suits were used as early as 1916 , the British army having adopted " coats of motley hue and stripes of paint " for snipers . Cott takes the example of the larva of the blotched emerald moth , which fixes a screen of fragments of leaves to its specially hooked bristles , to argue that military camouflage uses the same method , pointing out that the " device is ... essentially the same as one widely practised during the Great War for the concealment , not of caterpillars , but of caterpillar @-@ tractors , [gun] battery positions , observation posts and so forth . "

= = = = Cryptic behaviour = = = =

Movement catches the eye of prey animals on the lookout for predators , and of predators hunting for prey . Most methods of crypsis therefore also require suitable cryptic behaviour , such as lying down and keeping still to avoid being detected , or in the case of stalking predators such as the tiger , moving with extreme stealth , both slowly and quietly , watching its prey for any sign they are aware of its presence . As an example of the combination of behaviours and other methods of crypsis involved , young giraffes seek cover , lie down , and keep still , often for hours until their mothers return ; their skin pattern blends with the pattern of the vegetation , while the chosen cover and lying position together hide the animals ' shadows . The flat @-@ tail horned lizard similarly relies on a combination of methods : it is adapted to lie flat in the open desert , relying on stillness , its cryptic coloration , and concealment of its shadow to avoid being noticed by predators . In the ocean , the leafy sea dragon sways mimetically , like the seaweeds amongst which it rests , as if rippled by wind or water currents .

= = = = Motion camouflage = = = =

Most forms of camouflage are ineffective when the camouflaged animal or object moves , because the motion is easily seen by the observing predator , prey or enemy . However , insects such as hoverflies and dragonflies use motion camouflage : the hoverflies to approach possible mates , and the dragonflies to approach rivals when defending territories . Motion camouflage is achieved by moving so as to stay on a straight line between the target and a fixed point in the landscape ; the pursuer thus appears not to move , but only to loom larger in the target 's field of vision . The same technique can be used for military purposes , for example by missiles to minimise their risk of detection by the enemy . However , missile engineers , and animals such as bats , use the technique primarily for its efficiency rather than camouflage .

= = = = Changeable skin pattern / colour = = = =

Animals such as chameleon , frog , flatfish such as the peacock flounder , squid and octopus actively change their skin patterns and colours using special chromatophore cells to resemble their current background (as well as for signalling) .

Each chromatophore contains pigment of only one colour . In fish and frogs , colour change is mediated by the type of chromatophores known as melanophores that contain dark pigment . A melanophore is star @-@ shaped ; it contains many small pigmented organelles which can be dispersed throughout the cell , or aggregated near its centre . When the pigmented organelles are dispersed , the cell makes a patch of the animal 's skin appear dark ; when they are aggregated , most of the cell , and the animal 's skin , appears light . In frogs , the change is controlled relatively slowly , mainly by hormones . In fish , the change is controlled by the brain , which sends signals directly to the chromatophores , as well as producing hormones .

The skins of cephalopods such as the octopus contain complex units , each consisting of a chromatophore with surrounding muscle and nerve cells . The cephalopod chromatophore has all its pigment grains in a small elastic sac , which can be stretched or allowed to relax under the control of the brain to vary its opacity . By controlling chromatophores of different colours , cephalopods can rapidly change their skin patterns and colours .

On a longer timescale , animals like the Arctic hare , Arctic fox , stoat , and rock ptarmigan change their coat colour (by moulting and growing new fur or feathers) from brown or grey in the summer to white in the winter ; the Arctic fox is the only species in the dog family to do so . However , Arctic hares which live in the far north of Canada , where summer is very short , remain white year @-@ round .

The principle of varying coloration either rapidly or with the changing seasons has military applications . Active camouflage could in theory make use of both dynamic colour change and counterillumination . Simple techniques such as changing uniforms and repainting vehicles for winter have been in use since the Second World War . In 2011 , BAE Systems announced their Adaptiv infrared camouflage technology . It uses about 1000 hexagonal panels to cover the sides of a tank . The panels are heated and cooled to match either the vehicle 's surroundings (crypsis) , or an object such as a car (mimesis) , when viewed in infrared .

= = = = Countershading = = = =

Countershading uses graded colour to counteract the effect of self @-@ shadowing , creating an illusion of flatness . Self @-@ shadowing makes an animal appear darker below than on top , grading from light to dark ; countershading ' paints in ' tones which are darkest on top , lightest below , making the countershaded animal nearly invisible against a suitable background . Thayer observed that " Animals are painted by Nature , darkest on those parts which tend to be most lighted by the sky 's light , and vice versa " . Accordingly , the principle of countershading is sometimes called Thayer 's Law . Countershading is widely used by terrestrial animals , such as gazelles and grasshoppers ; marine animals , such as sharks and dolphins ; and birds , such as snipe and dunlin .

Countershading is less often used for military camouflage , despite Second World War experiments that showed its effectiveness . English zoologist Hugh Cott encouraged the use of techniques including countershading , but despite his authority on the subject , failed to persuade the British authorities . Soldiers often wrongly viewed camouflage netting as a kind of invisibility cloak , and they had to be taught to look at camouflage practically , from the enemy observer 's point of view . At the same time in Australia , zoologist William John Dakin advised soldiers to copy animals ' methods , using their instincts for wartime camouflage .

The term countershading has a second meaning unrelated to " Thayer 's Law " . It is that the upper and undersides of animals such as sharks , and of some military aircraft , are different colours to match the different backgrounds when seen from above or from below . Here the camouflage

consists of two surfaces , each with the simple function of providing concealment against a specific background , such as a bright water surface or the sky . The body of a shark or the fuselage of an aircraft is not gradated from light to dark to appear flat when seen from the side . The camouflage techniques used are the matching of background colour and pattern , and disruption of outlines .

= = = = Counter @-@ illumination = = = =

Counter @-@ illumination means producing light to match a background that is brighter than an animal 's body or military vehicle ; it is a form of active camouflage . It is notably used by some species of squid , such as the firefly squid and the midwater squid . The latter has light @-@ producing organs (photophores) scattered all over its underside ; these create a sparkling glow that prevents the animal from appearing as a dark shape when seen from below . Counterillumination camouflage is the likely function of the bioluminescence of many marine organisms , though light is also produced to attract or to detect prey and for signalling .

Counterillumination has rarely been used for military purposes . " Diffused lighting camouflage " was trialled by Canada 's National Research Council during the Second World War . It involved projecting light on to the sides of ships to match the faint glow of the night sky , requiring awkward external platforms to support the lamps . The Canadian concept was refined in the American Yehudi lights project , and trialled in aircraft including B @-@ 24 Liberators and naval Avengers . The planes were fitted with forward @-@ pointing lamps automatically adjusted to match the brightness of the night sky . This enabled them to approach much closer to a target ? within 3 @,@ 000 yards (2 @,@ 700 metres) ? before being seen . Counterillumination was made obsolete by radar , and neither diffused lighting camouflage nor Yehudi lights entered active service .

= = = = Transparency = = = =

Many marine animals that float near the surface are highly transparent , giving them almost perfect camouflage . However , transparency is difficult for bodies made of materials that have different refractive indices from seawater . Some marine animals such as jellyfish have gelatinous bodies , composed mainly of water ; their thick mesogloea is acellular and highly transparent . This conveniently makes them buoyant , but it also makes them large for their muscle mass , so they cannot swim fast , making this form of camouflage a costly trade @-@ off with mobility . Gelatinous planktonic animals are between 50 and 90 percent transparent . A transparency of 50 percent is enough to make an animal invisible to a predator such as cod at a depth of 650 metres (2 @,@ 130 ft) ; better transparency is required for invisibility in shallower water , where the light is brighter and predators can see better . For example , a cod can see prey that are 98 percent transparent in optimal lighting in shallow water . Therefore , sufficient transparency for camouflage is more easily achieved in deeper waters .

Some tissues such as muscles can be made transparent , provided either they are very thin or organised as regular layers or fibrils that are small compared to the wavelength of visible light . A familiar example is the transparency of the lens of the vertebrate eye , which is made of the protein crystallin , and the vertebrate cornea which is made of the protein collagen . Other structures cannot be made transparent , notably the retinas or equivalent light @-@ absorbing structures of eyes ? they must absorb light to be able to function . The camera @-@ type eye of vertebrates and cephalopods must be completely opaque . Finally , some structures are visible for a reason , such as to lure prey . For example , the nematocysts (stinging cells) of the transparent siphonophore Agalma okenii resemble small copepods . Examples of transparent marine animals include a wide variety of larvae , including coelenterates , siphonophores , salps (floating tunicates) , gastropod molluscs , polychaete worms , many shrimplike crustaceans , and fish ; whereas the adults of most of these are opaque and pigmented , resembling the seabed or shores where they live . Adult comb jellies and jellyfish obey the rule , often being mainly transparent . Cott suggests this follows the more general rule that animals resemble their background : in a transparent medium like seawater , that means actually being transparent . The small Amazon river fish Microphilypnus amazonicus and

the shrimps it associates with , Pseudopalaemon gouldingi , are so transparent as to be " almost invisible " ; further , these species appear to select whether to be transparent or more conventionally mottled (disruptively patterned) according to the local background in the environment .

= = = = Silvering = = = =

Where transparency cannot be achieved , it can be imitated effectively by silvering to make an animal 's body highly reflective . At medium depths at sea , light comes from above , so a mirror oriented vertically makes animals such as fish invisible from the side . Most fish in the upper ocean such as sardine and herring are camouflaged by silvering .

The marine hatchetfish is extremely flattened laterally , leaving the body just millimetres thick , and the body is so silvery as to resemble aluminium foil . The mirrors consist of microscopic structures similar to those used to provide structural coloration : stacks of between 5 and 10 crystals of guanine spaced about ¼ of a wavelength apart to interfere constructively and achieve nearly 100 per cent reflection . In the deep waters that the hatchetfish lives in , only blue light with a wavelength of 500 nanometres percolates down and needs to be reflected , so mirrors 125 nanometres apart provide good camouflage .

In fish such as the herring which live in shallower water , the mirrors must reflect a mixture of wavelengths , and the fish accordingly has crystal stacks with a range of different spacings . A further complication for fish with bodies that are rounded in cross @-@ section is that the mirrors would be ineffective if laid flat on the skin , as they would fail to reflect horizontally . The overall mirror effect is achieved with many small reflectors , all oriented vertically . Silvering is found in other marine animals as well as fish . The cephalopods , including squid , octopus and cuttlefish , have multi @-@ layer mirrors made of protein rather than guanine .

= = = Mimesis = = =

In mimesis (also called masquerade) , the camouflaged object looks like something else which is of no special interest to the observer . Mimesis is common in prey animals , for example when a peppered moth caterpillar mimics a twig , or a grasshopper mimics a dry leaf . It is also found in nest structures ; some eusocial wasps , such as Leipomeles dorsata , build a nest envelope in patterns that mimic the leaves surrounding the nest .

Mimesis is also employed by some predators and parasites to lure their prey . For example , a flower mantis mimics a particular kind of flower , such as an orchid . This tactic has occasionally been used in warfare , for example with heavily armed Q @-@ ships disguised as merchant ships .

The common cuckoo , a brood parasite , provides examples of mimesis both in the adult and in the egg . The female lays her eggs in nests of other , smaller species of bird , one per nest . The female mimics a sparrowhawk . The resemblance is sufficient to make small birds take action to avoid the apparent predator . The female cuckoo then has time to lay her egg in their nest without being seen to do so . The cuckoo 's egg itself mimics the eggs of the host species , reducing its chance of being rejected .

= = = Motion dazzle = = =

Most forms of camouflage are made ineffective by movement : a deer or grasshopper may be highly cryptic when motionless , but instantly seen when it moves . But one method , motion dazzle , requires rapidly moving bold patterns of contrasting stripes . Motion dazzle may degrade predators ' ability to estimate the prey 's speed and direction accurately , giving the prey an improved chance of escape . Motion dazzle distorts speed perception and is most effective at high speeds ; stripes can also distort perception of size (and so , perceived range to the target) . As of 2011 , motion dazzle had been proposed for military vehicles , but never applied . Since motion dazzle patterns would make animals more difficult to locate accurately when moving , but easier to see when stationary , there would be an evolutionary trade @-@ off between motion dazzle and crypsis .

An animal that is commonly thought to be dazzle @-@ patterned is the zebra . The bold stripes of the zebra have been claimed to be disruptive camouflage , background @-@ blending and countershading . After many years in which the purpose of the coloration was disputed , an experimental study by Tim Caro suggested in 2012 that the pattern reduces the attractiveness of stationary models to biting flies such as horseflies and tsetse flies . However , a simulation study by Martin How and Johannes Zanker in 2014 suggests that when moving , the stripes may confuse observers , such as mammalian predators and biting insects , by two visual illusions : the wagon @-@ wheel effect , where the perceived motion is inverted , and the barberpole illusion , where the perceived motion is in a wrong direction .

= = Civil applications = =

Camouflage is occasionally used to make buildings less conspicuous : for example , in South Africa , towers carrying cell telephone antennae are sometimes camouflaged as tall trees with plastic branches , in response to " resistance from the community " . Since this method is costly (a figure of three times the normal cost is mentioned) , alternative forms of camouflage can include using neutral colours or familiar shapes such as cylinders and flagpoles . Conspicuousness can also be reduced by siting masts near or actually on other structures .

Hunters of game have long made use of camouflage in the form of materials such as animal skins , mud , foliage , and green or brown clothing to enable them to approach wary game animals . Field sports such as driven grouse shooting conceal hunters in hides (also called blinds or shooting butts) . Modern hunting clothing makes use of fabrics that provide a disruptive camouflage pattern ; for example , in 1986 the hunter Bill Jordan created cryptic clothing for hunters , printed with images of specific kinds of vegetation such as grass and branches .

Automotive manufacturers often use patterns to disguise upcoming products . This camouflage is designed to obfuscate the vehicle 's visual lines , and is used along with padding , covers , and decals . The patterns ' purpose is to prevent visual observation (and to a lesser degree photography) , that would subsequently enable reproduction of the vehicle 's form factors .

= = Fashion , art and society = =

Military camouflage patterns influenced fashion and art from the time of the First World War onwards . Gertrude Stein recalled the cubist artist Pablo Picasso 's reaction in around 1915 :

I very well remember at the beginning of the war being with Picasso on the boulevard Raspail when the first camouflaged truck passed . It was at night , we had heard of camouflage but we had not seen it and Picasso amazed looked at it and then cried out , yes it is we who made it , that is cubism .

In 1919 , the attendants of a " dazzle ball " , hosted by the Chelsea Arts Club , wore dazzle @-@ patterned black and white clothing . The ball influenced fashion and art via postcards and magazine articles . The Illustrated London News announced :

The scheme of decoration for the great fancy dress ball given by the Chelsea Arts Club at the Albert Hall , the other day , was based on the principles of " Dazzle " , the method of " camouflage " used during the war in the painting of ships ... The total effect was brilliant and fantastic .

More recently , fashion designers have often used camouflage fabric for its striking designs , its " patterned disorder " and its symbolism . Camouflage clothing can be worn largely for its symbolic significance rather than for fashion , as when , during the late 1960s and early 1970s in the United States , anti @-@ war protestors often ironically wore military clothing during demonstrations against the American involvement in the Vietnam War .

Modern artists such as Ian Hamilton Finlay have used camouflage to reflect on war . His 1973 screenprint of a tank camouflaged in a leaf pattern , Arcadia , is described by the Tate as drawing " an ironic parallel between this idea of a natural paradise and the camouflage patterns on a tank " . The title refers to the Utopian Arcadia of poetry and art , and the memento mori Latin phrase Et in Arcadia ego which recurs in Hamilton Finlay 's work . In science fiction , Camouflage is a novel

about shapeshifting alien beings by Joe Haldeman . The word is used more figuratively in works of literature such as Thaisa Frank 's collection of stories of love and loss , A Brief History of Camouflage .

= = = Camouflage in nature = = =

Pioneering research

Beddard , Frank Evers (1892) . Animal Coloration : an account of the principal facts and theories relating to the colours and markings of animals . Swan Sonnenschein .

Cott , Hugh B (1940) . Adaptive Coloration in Animals . Methuen .

Darwin , Charles (1859) . On the Origin of Species . John Murray . Reprinted 1985 , Penguin Classics .

Poulton , Edward B (1890) . The Colours of Animals : their meaning and use , especially considered in the case of insects . Kegan Paul , Trench , Trübner .

Thayer , Abbott H ; Thayer , Gerald H. (1909) . Concealing @-@ Coloration in the Animal Kingdom . Macmillan .

General reading

Elias , Ann (2011) . Camouflage Australia : Art , Nature , Science and War . Sydney University Press . ISBN 978 @-@ 1 @-@ 920899 @-@ 73 @-@ 8 .

Forbes , Peter (2009) . Dazzled and Deceived : Mimicry and Camouflage . Yale University Press . ISBN 978 @-@ 0 @-@ 300 @-@ 17896 @-@ 8 .

Herring , Peter (2002) . The Biology of the Deep Ocean . Oxford University Press . ISBN 978 @-@ 0 @-@ 19 @-@ 854956 @-@ 7 .

Rothenberg , David (2011) . Survival of the Beautiful : Art , Science and Evolution . Bloomsbury . ISBN 978 @-@ 1 @-@ 60819 @-@ 216 @-@ 8 .

= = = Military camouflage = = =

Barkas , Geoffrey ; Barkas , Natalie (1952) . The Camouflage Story (from Aintree to Alamein) . Cassell .

Casson , Lionel (1995) . Ships and Seamanship in the Ancient World . JHU Press . ISBN 978 @-@ 0 @-@ 8018 @-@ 5130 @-@ 8 .

Newark , Tim (2007) . Camouflage . Thames and Hudson , with Imperial War Museum . ISBN 978 @-@ 0 @-@ 500 @-@ 51347 @-@ 7 .