

such things as the automatic induction of programs that perform probabilistic information processing, promise tantalizing reconciliations, and are still at the forefront of current research.

Fortunately, that the book nails its colors firmly to a restrictivist mast should not perturb readers of less Laplacian or more constructivist dispositions, given that the implications for the concrete computational and algorithmic scaffolding are relatively modest. Perhaps less fortunate is that this very modesty means that there can only be limited connections between the book's overall computational and implementational themes.

The book is published at a time when many of us are wondering about the date at which our artificially intelligent devices will be lordling it over us. It nicely points out that, although this prospect has arisen because of the capacity of modern 'deep' artificial neural networks (rather than automatically induced probabilistic programs) to learn, the way that these nets learn is currently far removed and generally far less statistically efficient than the way that we do so. One part of the difference is that nets use their vast training sets to recapitulate through learning what we are endowed with at birth by evolution. Of course, through a computational implementation of a Baldwin effect, this might ultimately be hardwired at the equivalent 'birth' of the nets. However, our abilities at learning from limited samples, at addressing the eternal dilemma between stability and plasticity [9], at adjusting appropriately to the volatility of the environment, and a host of other computational and algorithmic capacities might keep us on top for a while longer. It would have been good to have had more discussion of the converse, i.e. an examination of the progressively changing and enriching neural representations over the course of learning that one might be able to conduct more precisely in artificial neural nets.

The book is perhaps a little overly sanguine at the idea that the nets can only replace the sort of non-reflective calculations that correspond to the first 200–300 ms of unconscious processing by us; AlphaGo's famous victory over the former world champion Lee Sedol in the game of Go shows that this can be perfectly ample when coupled to

a modest reasoning capacity. Indeed, distillation, which is one computational equivalent of the sort of consolidation that happens in quiet wakefulness and sleep in us, could ultimately replace even this, given an adequately sized net.

Finally, the book is a bit relentlessly anthropocentric, perhaps stemming from Dehaene's ultimate interest in pedagogy — something whose existence outside human culture the book sternly questions. However, the key algorithmic and implementational processes and mechanisms — including the identified pillars of learning — are shared with many other mammals (and at least some birds), as even more generally is the need and capacity for adaptation to adjust successfully to the exigencies of a nasty, brutish, and changing environment.

In sum, this engaging book teaches us much about learning, while also showing how much more about learning there is to learn. One can only sympathize with the author as he details all the better ways that there would be to go about teaching us than using just the pages of a book. But after reading it, you will certainly feel more learned.

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Quick guide

Non-visual camouflage

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What is non-visual camouflage? For over 800 million years, the constant arms race between predators and prey has driven the evolution of ecological innovations aimed at improving the chances of capturing prey or avoiding being caught. One of the most fascinating of these is camouflage, where organisms avoid detection or recognition by unwanted receivers (i.e. predators or prey) by altering the sensory information they emit. Camouflage has independently evolved in a diverse range of animal taxa — from ants to whales — implying that it plays a fundamental ecological role, mediating trophic interactions throughout the food chain. When we think of camouflage, we generally imagine animals that resemble their visual surroundings. This is no coincidence: sight is our primary sense and our brains are particularly adept at noticing visual patterns. However, for many animals, vision is outweighed by other senses, reliance on which is often critical when interacting with their environments. For instance, sharks have an olfactory sense hundreds of times better than ours and use chemical information to locate prey over large distances. Thus, just as animals alter their visual appearance to avoid detection, there is likely to be similar pressure to conceal the non-visual information they emit to blend in, i.e. non-visual camouflage.

Why is non-visual camouflage so poorly understood? Humans are especially good at identifying visually interesting patterns and processes, which may help explain why visual camouflage has received far more research attention compared to non-visual camouflage. However, as our understanding of the sensory capabilities of animals has advanced, the degree to which non-visual information influences ecological



processes, such as predator-prey interactions, has become increasingly apparent. As a result, there has been a greater recognition of the need to examine species interactions from the 'point-of-view' of the organisms involved, without imposing our own sensory biases on them. This has led to the realisation that some phenomena that appear to be camouflage may serve a different purpose, that patterns and colours we see as gaudy may actually have an underlying camouflage function, and that non-visual camouflage may be far more widespread and complex than we realise.

Which non-visual senses are employed? When looking for non-visual camouflage we first need to determine how the potentially camouflaged animal's predators or prey sense the world to determine what cues may be concealed or modified. To date, most evidence for non-visual camouflage comes from animals altering the chemicals or sounds they produce; however, there is potential for animals to modify any source of sensory information used by unwanted receivers to locate and identify them (e.g. electrical currents, vibrations, or heat). Within multisensory environments, it is often the case that an animal's suite of predators or prey rely on different sensory systems and so animals may face pressure to conceal themselves on multiple fronts. For example, the caterpillars of the giant geometer moth (*Biston robustum*) are visually cryptic, resembling the twigs of their host plant, which conceals them from visual predators such as birds. However, they are also at risk from predatory ants that live on the plants and hunt via chemoreception. To combat this additional threat, these caterpillars incorporate plant compounds into their exoskeleton to prevent ants from recognising them as prey. Thus, these caterpillars have evolved both visual and chemical camouflage in tandem in order to hide from multiple predators using different sensory modes.

What animals use non-visual camouflage and how? Non-visual camouflage can occur in both



Figure 1. A diverse range of animals employ non-visual camouflage.

From top left: caterpillars of the giant geometer moth (*Biston robustum*) chemically resemble the plants they live and feed on; a similar mechanism has been identified in the coral-feeding harlequin filefish (*Oxymonacanthus longirostris*). Chemical camouflage can also occur independently of the diet, as is seen in the puff adder (*Bitis arietans*). Both great tits (*Parus major*) and southern right whales (*Eubalaena australis*) use acoustic camouflage, modifying their calls to prevent eavesdropping. Common cuttlefish (*Sepia officinalis*) modify their bioelectric fields to prevent detection. Photo credits (clockwise from top left): John Horstman/itchydogimages; Ken Yang/Flickr (CC BY-SA 2.0); Nick Jonsson/Flickr (CC BY 2.0); hедера.baltica/Flickr (CC BY-SA 2.0); E NOAA Photo Library/Flickr (CC BY 2.0); F Brian Gratwicke/Flickr (CC BY 2.0).

predators and prey from a wide range of habitats and ecosystems (Figure 1). Some of the best evidence to date comes from chemical camouflage in insects, which may not be surprising given their reliance on chemical signals for communication. However, chemical camouflage has also been identified in other taxa including fishes, birds and reptiles. Within these groups, chemical camouflage can occur via a number of different pathways. For instance, fishes have been shown to innately mask their odour, modify their waste so that it is less volatile, and change their odour via their diet. Acoustic camouflage is trickier to identify because, while many animals will limit the sounds they make to avoid detection, this

is often best classified as a form of hiding. In contrast, acoustic camouflage occurs where animals continue to produce auditory cues but modify them so that they are harder for receivers to detect. Evidence suggesting acoustic camouflage has been identified in a diverse range of animals. For instance, moths will modify their behaviour to prevent echolocation by bats, some passerine birds employ alarm calls that are hard for predators to detect, and baleen whale mother and calf pairs will alter the amplitude of their calls to prevent eavesdropping by predators such as orcas. As noted, camouflage mechanisms that employ other sensory systems are even less understood; nonetheless, the

evidence we do have is intriguing. For instance, some cuttlefish and weakly electric fishes will alter or cloak their electric fields to prevent detection by electroreceptive predators. Even some large dinosaurs may have had morphological adaptations to reduce the strength of vibrations produced while moving.

Does non-visual camouflage interact with other ecological processes? Almost undoubtedly. For instance, the need to alter signals to avoid detection can often conflict with the need to be highly noticeable, in order to communicate with others and attract mates. As a result, many of the sensory cues animals produce, such as colours, sounds, and chemicals, can have multiple purposes, depending on whether these are directed at wanted (e.g. a potential mate) or unwanted receivers (e.g. a predator). How animals that use non-visual camouflage balance the need to be simultaneously obvious and discrete is not well understood, but again will depend on the sensory modes of both types of receivers. Non-visual camouflage likely also influences aspects of the behaviour and ecology of animals more broadly, as the effectiveness of camouflage is directly dependent on the sensory characteristics of an individual's environment. For instance, just as green animals likely need to live in green habitats to benefit from visual camouflage, similar pressures may also be expected for non-visual camouflage too (e.g. chemical background matching). This would influence behavioural processes such as habitat selection, resource use, and movement, depending on how reliant individuals are on camouflage for survival, how flexible the camouflage is, the sensory modes involved, and the type of environment the animal lives in.

What's next? While there is now a greater understanding of non-visual camouflage in animals, countless interesting questions remain to be answered. For instance, many of the theoretical pathways and mechanisms posited over the years still await empirical testing

but could lead to fascinating new discoveries and insights into animal behaviour. Equally important is a better understanding of how different forms of non-visual camouflage overlap, and how they interact with and are distinct from other modes of deception used by animals, such as mimicry and hiding, both within and across sensory modalities. Understanding the ecological role of non-visual camouflage is especially important now as natural conditions rapidly change around the world. For instance, noise, chemical, vibration and light pollution all alter aspects of the sensory landscape in which animals live. We know that sensory pollution can disrupt the behaviour of animals, interfere with how predators and prey interact, and alter the effectiveness of visual camouflage, so it is likely that we are also disrupting how animals use non-visual camouflage, with unknown follow-on effects.

Where can I find out more?

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Primer Ferroptosis

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Iron is an essential micronutrient for microorganisms, plants, animals, and humans. However, iron overload can damage the organism through a variety of mechanisms, including the induction of cell death. Ferroptosis is defined as an iron-dependent form of regulated cell death caused by unrestricted lipid peroxidation and subsequent membrane damage. Ferroptosis can be triggered through either the extrinsic or the intrinsic pathway. The extrinsic pathway is initiated through the regulation of transporters (e.g., inhibition of the amino acid antiporter system xc⁻ or activation of the iron transporters transferrin and lactotransferrin), whereas the intrinsic pathway is mainly induced by blocking the expression or activity of intracellular antioxidant enzymes, such as glutathione peroxidase 4 (GPX4). In addition to small-molecule compounds and drugs, certain stresses (e.g., high temperature, low temperature, hypoxia, and radiation) induce ferroptotic cell death. The abnormal regulation of this process, which is connected to protein degradation pathways, such as autophagy and the ubiquitin–proteasome system, is associated with various pathological conditions, including acute tissue damage, infection, cancer, and neurodegeneration. Here, we discuss the core process and regulation of ferroptosis in mammalian cells, as well as its therapeutic implications in disease.

Historical overview

Cell death, including accidental cell death and regulated cell death, is closely linked with oxidative stress and plays a fundamental role in various organisms. Recently, the list of new types of regulated cell death has increased, each showing different characteristics in terms of the molecular machinery involved and the signals that are modulated. The original idea for the concept of ferroptosis came from the search for new therapeutic

