FURRY LOGIC

THE PHYSICS OF ANIMAL LIFE

Matin Durrani & Liz Kalaugher

'Packed with insight and information.'
Jim Al-Khalili, physicist and broadcaster

BLOOMSBURY

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INTRODUCTION

Furry Physics

It's tough being an animal. There's no central heating or air-conditioning to keep you at a safe temperature, no supermarket to provide supplies when you're peckish, and no walls to protect you. Jump into a river to catch fish and there won't be a towel ready to dry you when you wade soggily out, your body chilling fast. To survive, animals must use their senses, their wits, their mates, relations and pack-members (except for solitary species like the leopard), as well as their bodies, which have evolved over many years to suit their living conditions. And that's where physics comes in. Only recently have biologists and physicists realised just how impressive animals are when it comes to exploiting physics in their daily business of eating, drinking, mating and generally avoiding being killed. Even wet pet dogs use physics to shake themselves dry and soak anyone not quick enough to move away.

It's not that animals have worked out the principles of this science and designed their own bodies accordingly. It's that evolution has, over time, by gradual trial and error, come up with real-world systems that function well, using the science, principles and laws that humans call physics.

Animals got there first. The electric eel was firing off bursts of high voltage to kill crabs (see Chapter 5) and applying the principles of electricity long before scientists knew what it was. The eel doesn't understand electric currents, but we don't need to know anything about transistors or circuits to use a smartphone either. As long as the phone is smart, we don't have to be.

Worms without the wormholes

Before we kick off, a word of reassurance. This book is about how selected animals use physics to survive in the wild. If you're scared of physics, don't worry, we've kept things simple. You won't need to be an Einstein to follow what's going on. Don't expect anything weird like dark energy, Higgs bosons or wormholes – although we do mention worms at one point, or at the very least, snakes. On the other hand, if you are into physics, you'll be astounded by how often and how niftily your favourite science crops up in the animal world. From furry cats and dogs to spiny lobsters, mosquitoes and giant squid, physics is everywhere.

For physics lovers, the key thing to remember about biology is that pretty much everything is centred around sex or food. Physics, despite its obsession with the Big Bang, less so. For their species to survive, animals must pass on their genes by producing young. In almost all cases they need food to live long enough to breed, and perhaps to give them the energy to care for their young so that they too last into adulthood. A notable exception is the male fig wasp. This eats in its larval stage inside the fig, but once it metamorphoses into an adult it can no longer eat as its mouthparts are withered. Its sole purpose is to mate before it runs out of energy and dies.

If biology's your bag, the key thing to remember about physics is that it's much easier than biology. Honestly. If you're in a lab you have more control over your experiment. If you want to change just one thing (or one 'variable' in science-speak) to test its clout, it's a lot easier to do that inside a nice temperature- and humidity-controlled laboratory building sheltered from the weather than it is in a jungle. Or even a wildflower meadow, or, as we find out in Chapter 4, a zoo. And if you take the animal you're studying out of its environment, you don't know if that's made it behave differently. Leave that animal in its home, however, and you can't be sure if a variable you've changed has also altered something else – another animal or another variable – that you don't know about. And this might change your results without you being aware. So: biology hard, physics easy.

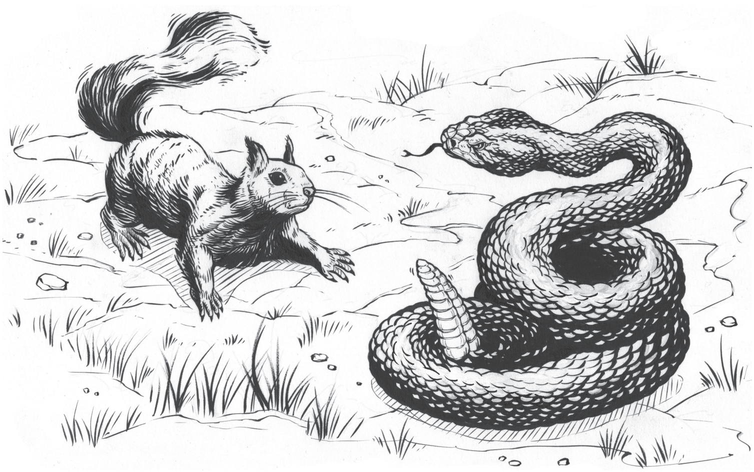
Now for the disclaimer: in *Furry Logic* sometimes we anthropomorphise, putting ourselves inside the heads of animals as if they were human. Biologists don't like this but it's easier to tell stories that way and so we won't apologise, or only a little anyway. And sometimes, whisper it, we simplify the physics a shade so that it doesn't block the narrative.

Some people turn to popular science seeking order and logic in today's messy world. But life's complicated. Sometimes the more you look at something the more complex it gets. It's like enjoying the beautiful colour and delicate scent of a rose, then examining it in close-up and seeing the velvety bloom on the petals, the veins at their pale base, the complex mini-forest of stamens and pollen dust at the centre, and the tiny hairs on the leaves underneath the bowl of the flower. Use a powerful microscope and you'll see the biological structures that make the rose work – its plumbing and individual cells. Unless you're seriously into botany, before you know it you've moved from pleasure and wonder to a bewildering world of fancy names and a flower that doesn't even look nice any more. It can be the same with physics explanations – there are levels upon levels, some that please everyone and others that are best left to the super-enthused and the genius. Here we've aimed for a level that remains fun; sometimes this means glossing over the geekiest details in the interests of beauty and simplicity, and we hope you're happy with that. If not, you'll probably enjoy looking up the equations and finer points yourself.

This book isn't an exhaustive account of the behaviour and characteristics of every single animal that applies physics. That would make it very long. Instead, each chapter covers a certain aspect of the science – heat, forces, fluids, sound, electricity and magnetism, light – and showcases its basic principles through the activities of a hand-picked set of animals. As the focus is on how animals use physics in their daily lives, we've chosen creatures, from peacocks to octopus and from elephants to bees, that actively take advantage of physics in drinking, catching their food, regulating their body temperature, defending themselves and more. It's more of a 'howdunit' than a whodunit, though you're unlikely to guess some of the answers.

One thing we don't look at, simply because there's enough material for a book in its own right, is how humans are exploiting their knowledge of the animal world for their own devices. So we don't cover how physicists developed heat sensors inspired by the structure of butterfly wings or created Velcro by studying how burrs stick to a dog's coat. Known as 'biomimetics' or 'bioinspiration', that field is interesting but well trodden. We do, however, become distracted – briefly – by a hearing aid based on elephant communication. Another topic out of our remit – again because others have tackled it – is the 'collective behaviour' of animals, such as flocks of birds flying in unison, the movement of penguins through a huddle, or ants working together to build a raft.

In our book the individual animals are the stars of the show.



CHAPTER ONE

Heat: The Warm-up Chapter

Gender-swapping snakes * Floppy-skinned dogs
* Mosquitoes that wee blood * Killer bees
* Hot-tailed squirrels * Vipers that 'see' heat
* Beetles that 'hear' infrared

It's getting hot in here

In *Indiana Jones and the Raiders of the Lost Ark*, dashing archaeologist Henry 'Indiana' Jones, played by Harrison Ford, faces his worst nightmare. Terrified of snakes, he must brave a secret Egyptian chamber teeming with the reptiles to stop the Ark of the Covenant falling into enemy hands. As in many movies, the scene draws on this animal's classic image as a creature of both evil and power.

Steven Spielberg, however, had more than symbolism on his mind. After scouring every pet shop in London for snakes, the movie director's staff had to cut up rubber hoses to make up the numbers. Even some of the 'snakes' weren't snakes but legless lizards, a difference that's crucial to a biologist, if not to a desperate film crew. Like the slow worm in your compost heap, legless lizards are – as their name suggests – lizards whose legs have shrunk or disappeared.

The actors' motto 'never work with children or animals' could have been coined with snakes in mind. These reptiles bite. They slither. They're scary. But it's not just film-makers who have problems. Biologists studying snakes in the wild have a tricky time too. Snakes are hard to track down, and once a snake has spotted you it'll slide away or, worse, inject or spray you with venom that could kill if it gets under your skin or into your eyes.

Luckily for our story's non-phobic hero, Rick Shine from the University of Sydney in Australia, one snake is an exception to this 'difficult-to-work-with' rule. Catch it at the right moment and it barely cares if you pick it up. Shine could, if he wanted to, put these reptiles in a car and take them for a ride. Up to a point, as we'll find out later, he did. In autumn, winter and spring the red-sided garter snake (*Thamnophis sirtalis parietalis*) hangs out, like Indy's nemeses in *Raiders of the Lost Ark*, in huge groups, sometimes tens of thousands strong (there's a number to make a film director jealous). They won't be in a secret Egyptian chamber, but in limestone cracks under the frozen soil of the Canadian prairies in the province of Manitoba. For this snake is a record-breaker: it's the most northerly-living reptile in the western hemisphere.

Living where temperatures plummet to -40°C and snow coats the ground for eight or nine months a year seems crazy. Reptiles are ectotherms (from the Greek for 'heat from the outside') and can't generate their own body heat by burning food. Instead they rely on outside sources like the Sun, basking in its rays until they're warm enough to move fast and reproduce. Faced with freezing conditions, red-sided garter snakes huddle together for warmth in their winter hidey-holes and brumate, the snake equivalent of hibernation.

But being in Manitoba brings benefits for the red-sided reptiles, and for those studying them too. For a start, once it arrives, summer is warm, with temperatures touching 30°C. In April or May the snakes emerge and writhe around on the barren soil in groups hundreds or thousands strong. This sight, which looks like a giant tangle of squirming spaghetti, has intrigued people for years. What are the snakes up to?

With a plot that even Spielberg would be proud of, the mystery of the red-sided garter snake involves cool physics, lots of sex and a soupçon of gender-swapping. Not among Shine and his colleagues, we must stress, but the snakes themselves.

Great garters

Where are our manners? We should get to know this snake before we pry into its sex life. First let's meet the wider family. Garter snakes live throughout North America, although only those species that dwell where winters are extra-cold brumate. You'll find these reptiles in woods, forests or grasslands as long as there's water nearby. About half a metre long, they're venomous enough to kill small prey but not humans. Favourite snacks include frogs and fish, though the snakes will also feed on earthworms, rodents and small birds.

As for red-sided garter snakes, these reptiles don't, at first glance, live up to their name; they're black with cream stripes running the length of their body. Their red sides lie beneath overlapping scales and you can only see them if the snake puffs up its body in annoyance. During Manitoba's three or four months of summer, the reptiles make the most of the warmth and can stray more than 15km (9 miles) from their dens in search of food.

When the first chill hits the air – in August, no less – the snakes head back to their bunkers. At first they stay down there only at night or when it's cloudy. Once the daytime temperature drops below freezing, however, the reptiles put themselves under house arrest and snuggle together ready for nine months of cold. Their winter homes lie 6m (20ft) underground, below the frostline. At 10°C, the 'indoor' temperature is no summer's day but balmier than the -40°C outside. While they brumate, the snakes barely expend any energy, existing almost in suspended animation. They eat nothing and hardly breathe, getting up only now and then for a drink of water.

All of a slither

Stand by one of the snake pits in or around the village of Narcisse in late spring, the long-awaited sunshine warming your face, and you'll enjoy one of the most unusual sights in nature. Facing you will be a writhing carpet of mud-caked reptiles that have just emerged from their burrow and are huddling together once more. Stare closely and you'll notice something even more odd: almost all the snakes are males. At about 45cm (18in) long, they're some 15cm (6in) shorter than the females.

Undaunted by their smaller size, the male snakes venture outside several weeks before the females. By lying in wait, each hopes to be first to mate. As they slither past one another, the early-risers flick their tongues in search of chemicals called pheromones that the females release through their skin. After nine long months of brumation, sex seems to be the males' number one aim.

But there's a hitch. As soon as the females emerge from their lair, most leg it (as far as that's possible for a snake). Any who are slow off the mark become the centre of attention in a frenzied mating ball of tens or even hundreds of amorous males, each trying to loop his body around her so he's in the right position to mate. The female finds this stressful and does what she can to escape. With males outnumbering females by 10 or more to one, a male's chances of reproducing are slim.

The giant tangle of male snakes and these smaller mating balls are freaky enough, but something even weirder's going on. Look carefully and from time to time you'll see males give their full attention not to a female, but to another male. We're not being sexist but some males' behaviour is most ungentlemanly. Literally. He-snakes pretend to be she-snakes, or 'she-males' in the scientific lingo, giving off pheromones to impersonate females. She-males are easy to spot: they're the same length as other males but, having slithered from underground later, are still coated in mud. Rarely courting 'other' females, these transgender snakes crawl around sluggishly instead. Soon the 'real' males jump on them.

Harder than identifying the she-males is understanding what they're up to. If he wants to mate with a female, why does a male pretend to be the same sex as her? This puzzle set biologists scratching their heads. Perhaps becoming a she-male gives a male a reproductive edge so he can steal sperm from other males or avoid attack from larger rivals. But Rick Shine wondered if hanging out in a giant heap isn't only about reproduction. Could it also be a matter of heat?

Reptiles in the bag

Fortunately biology was on the researchers' side. You'd think desperate-to-mate garter snakes wouldn't take kindly to interference. But in late spring, Shine and his colleagues can do what they like with the reptiles – male, she-male or female. Pick them up, measure them, put them in a bag; the snakes don't have the energy to care, making them almost ludicrously perfect for study. That's why Shine made a pilgrimage from Australia to snake dens near Narcisse seven years out of eight from 1997 to 2004. 'Having 10,000 amorous snakes in an area the size of a living room is a snake biologist's idea of heaven,' he says.

To find out the she-males' secrets, Shine and his colleagues simply sat in the grass alongside red-sided garter snakes that were fresh from their winter quarters. Grabbing individual she-males by the tail, the researchers presented them to 'real' males to see how they'd react. The males almost always found the she-male a turn-on, pressing their chins on him/her and lining up their bodies. So males definitely fall for the she-males' pheromone charms. But what's in it for the she-males?

Time for a more cunning plan. Shine kept one group of she-males at 10°C, the temperature of their bunker. He warmed another batch of she-males to 28°C by putting them in cloth bags and placing them on the electrically heated front seats of the team's four-wheel-drive Yukon hire car. Next the team brought the two groups to a common temperature of 25°C, heating the cool snakes up on the car seats, while letting the warm group chill off naturally.

Holding each 25°C she-male by its tail, Shine presented him/her to five different males. As expected, the males flicked their tongues faster and tried to sidle up to the she-male. But their interest didn't last forever. The guys stopped sniffing around a snake from the 'warm' group within about three hours. 'Cool' snakes won attention for five hours. The males' loss of interest revealed that the she-males had stopped gender-swapping and gone back to being simple males, with the 'warm' she-males reverting to type faster than the 'cool' ones. The conclusion was clear: male red-sided garter snakes become she-males to warm up as fast as they can. By pretending to be a female, a she-male entices other males to press themselves against what they see as a potential mate. Rubbing against his/her warmer rivals, the cold she-male draws heat generated by their muscles into his/her own body. Heat, as we'll hear later, only ever flows from hot to cold.

Snakes and ladders

Stealing heat from a fellow animal is known as kleptothermy (not to be confused with a compulsion to race out of the supermarket with jars of coffee stuffed under your coat – that's kleptomania). As they're long and thin, snakes have a huge surface area for their volume, so they lose heat faster than if they were round and cuddly. Heat is a precious commodity in the chilly Manitoban spring; it's about 10°C if you're lucky at this time of year, the same as underground. By sliding against each other in a giant heap, snakes can cut how much heat they lose. It's like camping on a cold night: snuggling up to someone in your tent keeps you both warm.

Acting the she-male lets a recently emerged snake warm up pronto from his winter slow-down. It's vital to act quickly. Cold and sluggish after months underground, he's a target for crows, who'd love nothing better than eating a lethargic snake. Warming up will help him move fast enough to avoid the bird's clutches. Gender-swapping has more underhand benefits too; it distracts a she-male's rivals from the real females, making the males waste precious energy on unproductive relationships. Meanwhile, the she-male saves energy by not bothering to have sex. As the proverb goes, keep your friends close but your enemies closer.

Originally biologists thought only some male red-sided garter snakes have a she-male phase after brumation. It turns out they all do, though the gender-swapping doesn't last forever. After warming up for a day or two, most she-males revert to being male and head off on their summer travels. The bulk of the courting and mating between real males and females happens in small groups far away from the snakes' winter dens.

So 'absurdly easy to investigate' are the red-sided garter snakes in spring that Shine was able to knock out more than 40 scientific papers from those seven trips he made to the wilds of Canada. 'One can frame a novel idea one evening, test it the following day, and devise a follow-up experiment over dinner the next evening,' he says. With the snakes so obliging, perhaps Spielberg should have taken a leaf out of Shine's book and filmed that famous snake scene in *Raiders of the Lost Ark* up in Canada.

The heat is on

During this sizzling saga of snake skulduggery we blithely threw around terms like heat and temperature. With a bit of luck you hardly even blinked. Heat is a word we use every day. We talk about the heat from the Sun or being in the heat of an argument, and we all know what it's like to feel hot or cold. Yet even the biggest brains in physics once found it hard to understand what heat really is. Back in the eighteenth century, most scientists thought heat was an invisible, weightless fluid called caloric that slinked its way from a hot object to a colder one. Though we might laugh at the notion of caloric today, it took an experiment in 1798 involving animals – two horses, and a man studying cannon manufacture in Munich – to knock the idea on the head. American-born Brit Benjamin Thompson (1753–1814) made the horses walk round in circles, driving a metal drill bit so that it bored a hole in a 2.7kg (6lb) brass cylinder in a vat of water. After two and a half hours, by which time the horses must have been as bored as the cylinder, both the brass and the water were extremely hot. 'It would be difficult to describe the surprise and astonishment expressed in the countenances of the by-standers, on seeing so large a quantity of cold water heated, and actually made to boil, without any fire,' Thompson wrote.

Where did this heat come from? Rub your hands together and you'll get a clue. When two surfaces, such as two palms or a drill bit and a cannon-in-the-making, move against each other, they generate a force known as friction. This resists the movement and converts some of its kinetic energy – the energy of motion – into thermal energy, otherwise known as heat. Friction features again in the next chapter, along with some ancient Greeks and an ice-hockey puck. But the boring horses (anyone remember the old *Yellow Pages* category 'Boring, see Civil Engineers'?) didn't do all the work. By showing that the material properties of the boring rods, brass and water hadn't changed, and that the water warmed up for as long as the horses kept moving, Thompson proved that none of them had gained or lost caloric fluid. Yet heat had still transferred. Caloric fluid, although a handy explanation, didn't exist. Instead, Thompson thought heat was a form of motion, which, if you think of both concepts as types of energy, is true. But despite his and the horses' efforts, it took many other bright minds – including that of the Manchester-born James Prescott Joule (1818–89) – half a century to bury caloric theory once and for all.

Get a move on

Joule was manager of the family brewery but found himself sidetracked by science. He installed a lab and heated water with motion just as Thompson had done. No horsepower this time: he attached a weight to a string so that as it fell it swooshed a paddle wheel round in a tank of water. Joule was then able to calculate the mechanical work done by the falling weight. By measuring how much heat this work created in the water, he linked the mechanical energy needed to perform the work to the thermal energy it made. This experiment helped develop the principle of conservation of energy, which in a nutshell says that 'energy is neither created nor destroyed'. Instead it shifts from one form to another – in Joule's experiment, from mechanical to thermal. In a light bulb, the electrical energy of the flowing current turns into light and heat, while animals convert the chemical energy in their food into mechanical energy to move around.

The transfer of energy between heat and other forms is known as thermodynamics, with the first law of thermodynamics incorporating the principle of conservation of energy. There are four laws in total, and they are numbered – unconventionally – from zero to three. Physicists added the zeroth law of thermodynamics in the twentieth century after describing the first, second and third laws the century before. The numbering had to go backwards; the zeroth law is like a prequel. If the first, second and third laws of thermodynamics were *Star Wars*, *The Empire Strikes Back* and *The Return of the Jedi*, the zeroth law would be *The Phantom Menace* (or, if you're a *Star Wars* purist, *The Revenge of the Sith* – physicists, we need you to come up with a couple more laws of thermodynamics to make this analogy work properly).

As a result of his paddle wheel and other efforts, Joule gives his name to a unit of energy: one joule (J) is the energy transferred (or work done) to an object when a force of one newton (N) moves that object one metre. That's roughly the energy needed to lift a small apple a metre into the air (more on forces and newtons in the next chapter, including details of an excellent hairstyle and how to walk on the ceiling). After an absence of almost four decades, the Joule beer brand was relaunched in 2010 but its lack of physics-based ale names is disappointing (anyone for a pint of Dark Energy or Stellar Artois?). Joule's name is a familiar sight on food packaging too: one 25g (1oz) packet of salt-and-vinegar-flavour crisps that we ate for research purposes provided 540,000J (540kJ) of energy. That's the same as 130 food calories (where 1 food calorie, or strictly speaking, 1 kilocalorie, equals 4,184J). The calorie, named after caloric fluid, is out of date but calories still taste good even if they're not worth counting any more.

Today we define heat as a form of energy transfer. Going one better than caloric fluid, which doesn't exist at all, heat exists only when two objects are at different temperatures. Then it flows between them until they reach the same temperature or, in science speak, are in thermal equilibrium. At this point the energy transfer stops and the heat ceases to exist. The energy formerly known – and transferred – as heat is incorporated into the kinetic energy of the atoms or molecules jigging about inside the previously cooler objects, making them move faster. At all temperatures above absolute zero (-273.15°C or, in the geek's temperature scale of choice, 0 kelvin, or K), such particles jig about all the time. In a gas or liquid, they move about freely, while in a solid they vibrate around their 'fixed' positions. That's what temperature is: a measure of the average kinetic energy of the atoms or molecules in an object. Something at a higher temperature, with more energy in its molecules, can transfer heat to something that's cooler, like the ice cream you've just put on your hot apple pie. In other words, temperature is a measure of an object's ability to transfer heat.

But how does heat transfer work? Take those garter snakes. When a cold and lethargic she-male tricks, with the aid of his/her female-faking pheromones, 'real' males into huddling around him, how does their heat work its way out through their skin and into the she-male's body? It's not as if the snakes swap molecules, even if passing on their DNA is the duped males' number one aim. Instead, the snakes use conduction to steal body heat (in the physics sense; they're not waving a stick in front of an orchestra or checking train tickets). Where they're pressed up close against the cold she-male, faster-jiggling molecules in the warm 'real' males bash against the she-male's slower molecules. These collisions transfer some of the speedy molecules' energy to the neighbouring slowcoaches. For the she-male's molecules, it's like being jostled by a fast-moving crowd; they end up moving faster themselves. The resulting heat transfer lowers the average kinetic energy of the molecules in the real males, reducing their temperature, and boosts the average kinetic energy of the molecules in the she-male, raising his/her temperature. Conduction like this, with two objects at different temperatures in close contact, is just one of the ways of transferring heat; more on the other two soon. But first, let's go to the dogs …

Twist 'n' shake

… via one of humanity's greatest inventions: the hot bath. Perfect for idle contemplation and the occasional Archimedes-style 'Eureka!' moment. Showers might save water but they don't give you time to think. So there you are, lying in the bath with your favourite popular-science book, the scent of lavender wafting in the steam, Vivaldi in the background and a mug of peppermint tea on the corner of the tub. Bliss. You even manage to keep the pages dry when your mind wanders for a second and you wake with your mouth dipping below the surface. Hmm. Lavender soap doesn't taste as good as it smells.

Still, everything else is perfect. If you cool off, that's easily fixed. Just add more water from the hot tap and carry on doing nothing. The hot water plummets to the bottom because of gravity, then rises to the top as it's less dense – it has fewer molecules in a given volume than the rest of your now too-cool-for-comfort bathwater. As it gains height, the hot water pulls colder, denser water from the other end of the bath to the place it's just left. The result is a convection current that mixes everything up and distributes the heat without you having to lift a finger (though a quick swoosh with your hand works wonders even more quickly).

Convection – the second way of transferring heat – occurs in all liquids and gases because their atoms or molecules can move about freely. Conduction, in contrast, works best in solids, where the atoms or molecules are confined near set positions and tend to be closer together, although it can take place in liquids and gases too. So you can thank two types of physics for warming you up in the bath: convection moves the hot water to you and conduction gets the heat into your body, just as it warms a she-male garter snake in a mating ball. All's well again.

Eventually your fingertips become pale and wrinkled and you decide to get out. Disaster! As you heave yourself out of the tub, water dribbling down your body, you realise your towel is in the wicker laundry basket in your bedroom. The one your aunt gave you. Curses. It was toasty warm in the bath but now you're freezing as you scurry across the corridor, leaving sodden footprints on the carpet.

When you get out of a bath, as much as 0.5kg (1lb) of the liquid stays on your body – about 0.5 per cent of your total mass (please accept our apologies for commenting on your weight). In volume terms, that's roughly half a litre, or a small carton of milk. Most of the water runs off but what remains evaporates: the hottest, fastest-moving molecules escape through the surface of the liquid into the air, leaving cooler, more sluggish molecules behind. The average temperature of the remaining water falls, cooling you down.

Evaporation's handy in summer when you sweat, your body deliberately creating pools of water on your skin to cool you. It's also useful when a dog pants with his tongue out to let saliva evaporate from his mouth. But this physics phenomenon isn't ideal if you're towel-less and dripping dry in cold air after a bath. If there's a draught from a leaky window, you'll feel colder still as the moving air whisks the escapee water molecules away from the surface of the water droplet, giving others more chance of jumping out and hastening the evaporation. It's why climbing out of an open-air swimming pool on a windy day is so bracing. In the UK, at least.

Water on your skin also cools you by drawing thermal energy out of your body through conduction; water conducts heat about 25 times better than air as its molecules are nearer each other. Together, conduction and evaporation mean you'll feel much colder if there's a layer of water next to your skin than if there's only air. Grabbing a towel and drying yourself off as fast as you can is the only way forward.

Fur enough

We might have towels, even if we left them in the bedroom, but animals don't. A furry animal – be it dog, bear, panda or hamster – can trap a lot of water between the hairs of its coat. The bedraggled fur of a rat holds around 5 per cent of the animal's total mass as liquid. Scaled up to human terms, that would be like us having 4 or 5 litres (7–9 pints) of water on our skin when we step out of the bath, 10 times more than normal. But it could be worse. At least the rat's not an ant covered in tiny hairs that hang on to a whopping three times its body weight in water.

Having fur this wet could cause a serious drop in body temperature as evaporation does its work. Or if, like dogs, other mammals, birds and a few types of fish, the animal's an endotherm and so generates its own heat, then its sopping fur could cause its energy levels to plummet as it burns fuel to stay warm. Animals make big efforts to stay at the same temperature because their bodies work best only within certain limits. In endotherms, that range is generally just a couple of degrees Celsius (we're ignoring hibernation here). Reptiles, butterflies, moths and other ectotherms, which don't create much heat themselves, often cope with a wider span of body temperatures. Red-sided garter snakes, for example, are OK at the 10°C of a Canadian spring day but faster-moving and safer when their bodies are at 25°C. As a rule, ectotherms don't need to eat as much as endotherms, but there are downsides too. If ectotherms want to move far they must first lie around in the sunshine, they can't move fast for long, and they can't live anywhere too cold. Ectotherms also find it harder to be active at night (though geckos – see Chapter 2 – are nocturnal).

Enough of geckos, rats, pandas and ants – we're trying to talk about dogs. As mammals, they're endotherms and their bodies need to be about 38–39°C. Below 37°C or above 40°C and it's time to take your pooch to the vet (though don't rely on us for medical advice – only one of us has a first-aid certificate and it's out of date). Like us, if dogs are too hot, their metabolism (the rate their body burns food to release energy) speeds up and they use their resources too fast. Also, if the enzymes that enable those energy-releasing reactions get too warm, they will stop working. No energy means no life. Too far below their ideal temperature and those enzymes don't work well either. The dog's metabolism slows, along with its heart rate, breathing and brain activity. If the animal gets too cold, all these essential operations will stop.