The agenda

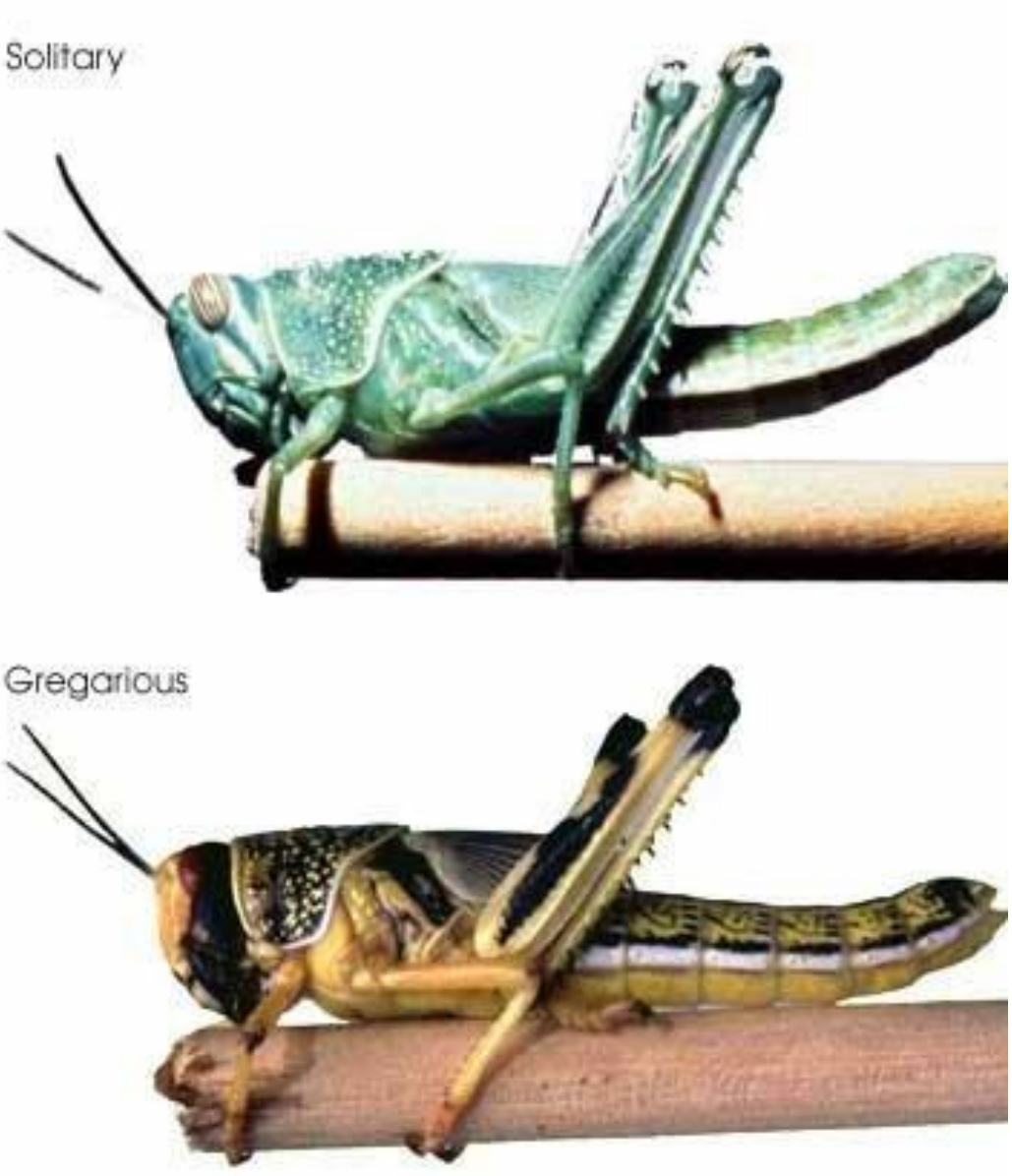
1. **Axolotl**
2. **Coral**
3. **Earthworm**
4. **Cuckoo**
5. **Mule**
6. **Herring gull**
7. **Squirrel monkey**
8. **Peacock**
9. **Honey bee**
10. **Naked mole rat**

Locust

Locusts

- **Locusts are not unique species. Rather, they are just species of grasshopper who are swarming.**
- **In so doing, they change their appearance as well as their behaviour**
- **A grasshopper can turn into a locust in around 4 hours**

Locusts



Locusts

Here is what apparently happens:

- **A bunch of grasshoppers become overcrowded**
- **They therefore happen to touch each other more often**
- **This increases their levels of serotonin**
- **This causes them both to eat more and to become mutually attracted**
- **So, they both breed much more quickly and stick together**
- **Then they run out of food and swarm**

Flatfish

A ray

A flatfish (e.g. halibut)

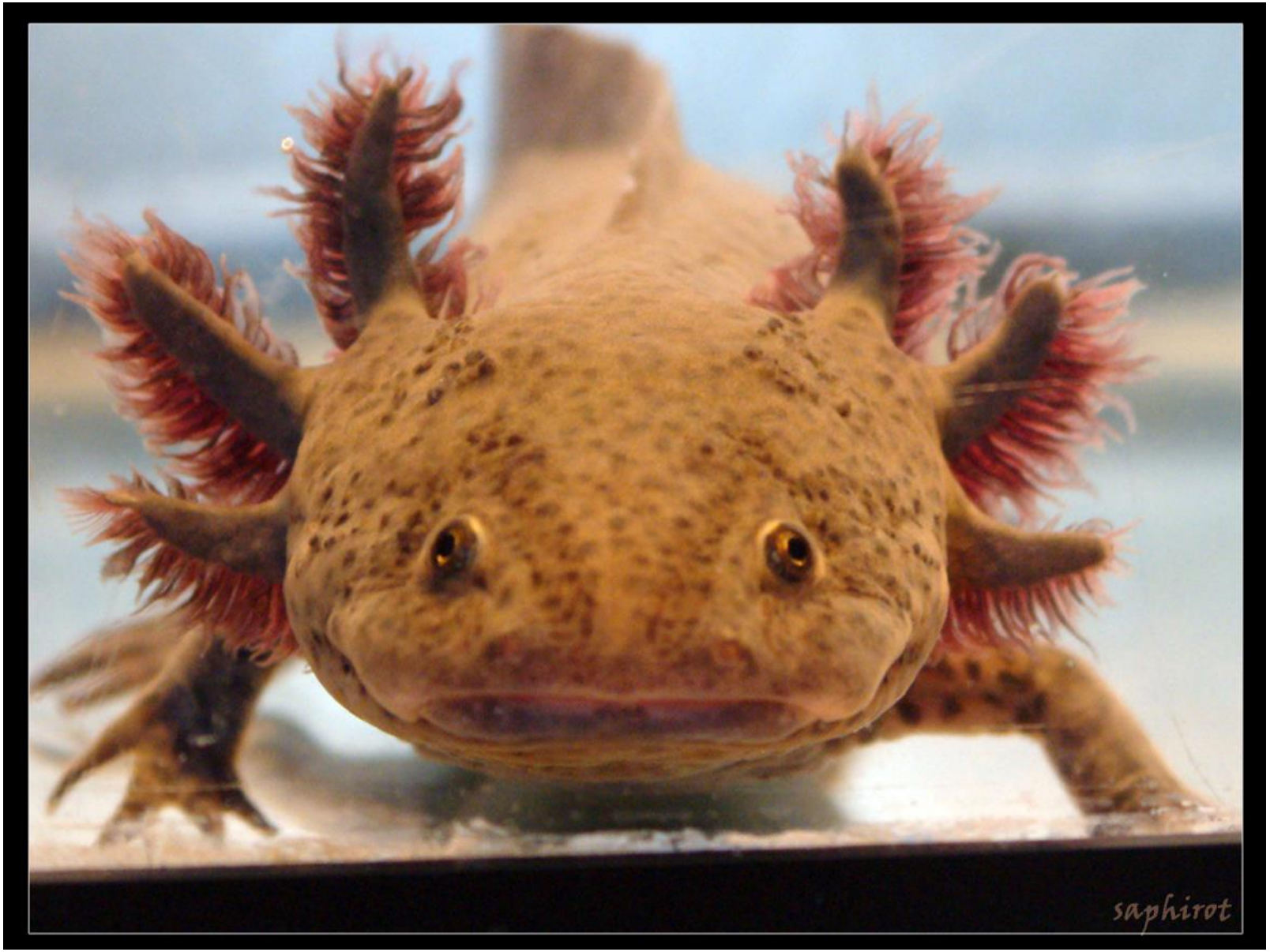
Flatfish

From Darwin:

- **Adult flat fish have both eyes on the same side of the head**
- **But, when babies, have normally-placed eyes**
- **Lacking swim bladders, they can't stay long in a vertical, swimming position**
- **So, they fall to the bottom and often turn onto their side so that one eye can see upwards**
- **And, in so doing, their other eye often gets pressed into the upper part of its orbit**
- **And, when young, their skulls are cartilaginous and flexible**
- **And, over time, it becomes distorted and the eye automatically moves**

1.
Axolotl

What is this animal?



Metamorphosis

- **Human adults look reasonably like human babies**
- **Ditto dogs. Ditto birds.**
- **So, we tend to think that it is generally true**
- **But it isn't; rather, most(?) animals metamorphose**
- **The larval form focuses on eating and growing**
- **The adult form focuses on mating and reproducing**
- **Think caterpillars and butterflies**

Caterpillars and butterflies

In passing:

- **The caterpillar contains both the caterpillar and butterfly cells**
- **As it grows, its cells don't divide**
- **Rather, its caterpillar cells grow in size whilst its butterfly cells stay small**
- **Then, during metamorphosis, the butterfly cells develop by using the caterpillar cells as food**

A ladybird – adult and larva

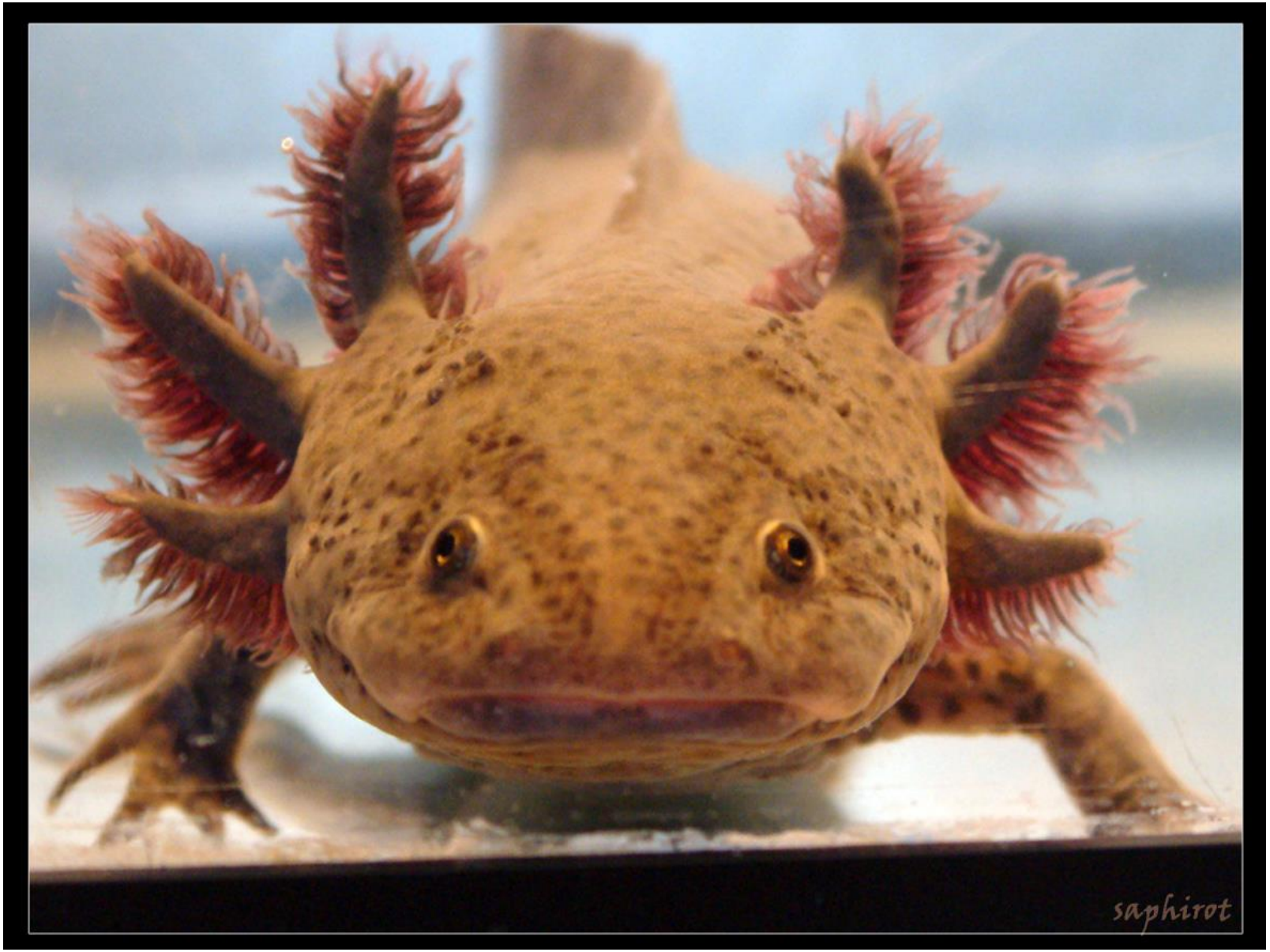
Salamanders

- **Salamanders, like frogs, are amphibians**
- **The larva lives under water, has gills and mainly eats vegetable matter**
- **The adult lives on land, has lungs and is mainly a carnivore**
- **Newts are a type of salamander**

Adult salamander

Salamander larva

Adult axolotl



Axolotls

- **A larval axolotl is like the larva of any other salamander**
- **But it never metamorphoses, so the adult is like the larva**
- **One day, a biologist injected an axolotl with thyroid hormone**
- **And, lo and behold, it metamorphosed into a standard looking salamander, the first such axolotl to have ever existed**

Axolotls (cont)

- **Effectively, the axolotl reaches sexual maturity whilst still a larva and never gets around to becoming physically adult**
- **Similarly, some biologists regard humans as juvenile apes (human and chimp babies look more alike than do their adult forms)**

2.
Earthworm

Earthworms

Darwin: along with corals and humans, earthworms are the most important animals on the planet

Earthworms according to Darwin

"In 1869, Mr. Fish rejected my conclusions with respect to the part which worms have played in the formation of vegetable mould, merely on account of their assumed incapacity to do so much work. Here we have an instance of that inability to sum up the effects of a continually recurrent cause, which has often retarded the progress of science, as in the case of the principle of evolution. Although this objections seemed to me to have no weight, I resolved to make more observations by attacking the problem on another side; namely, to weigh all the castings thrown up within a given time in a measured space, instead of ascertaining the rate at which objects left on the surface were buried by worms."

Darwin therefore did things like spreading chalk (in 1842) and seeing how far it sunk (by 1871)

Earthworms' impact on the earth

- **Swallow earth both to excavate their burrows and to extract any nutritious, organic matter**
- **Excrete on the surface (castings)**

Benefits:

- **Decomposition is aided by both being on the surface and having been through the worms**
- **Texture is improved by both only small particles being swallowed/excreted and by trituration**
- **Germination is aided by the seeds getting covered**
- **Aeration and drainage is improved by the burrows, etc**

Earthworms' sinking of objects

- **0.5cm thick layer swallowed and excreted each year (so 5cm in 10 years, and then more slowly)**
- **Equates to 10 tons on an acre of land**
- **Involves around 50,000 worms at any one time who collectively weigh around 160Kg**

So:

- **Anything larger than the worms can swallow gradually sinks**
- **Which, in turn, preserves these larger objects**
- **So, archaeologists ought to be grateful!**

3.
Coral

How was this atoll reef formed?

Coral

- **‘Coral’ is used to refer both to the animal and to the hard material that it leaves behind**
- **The coral organism is closely related to anemones and jellyfish**
- **Coral reefs are made out of secretions by the coral organisms (as a form of exoskeleton)**

It was Darwin who worked out how coral reefs form. His theory was controversial for many years but is now accepted

Two apparent paradoxes

Paradox 1: coral reefs are rich ecosystems but are usually surrounded by oceans which lack nutrients

Paradox 2: coral can only live in shallow water but are often surrounded by deep water

Resolution of the first paradox

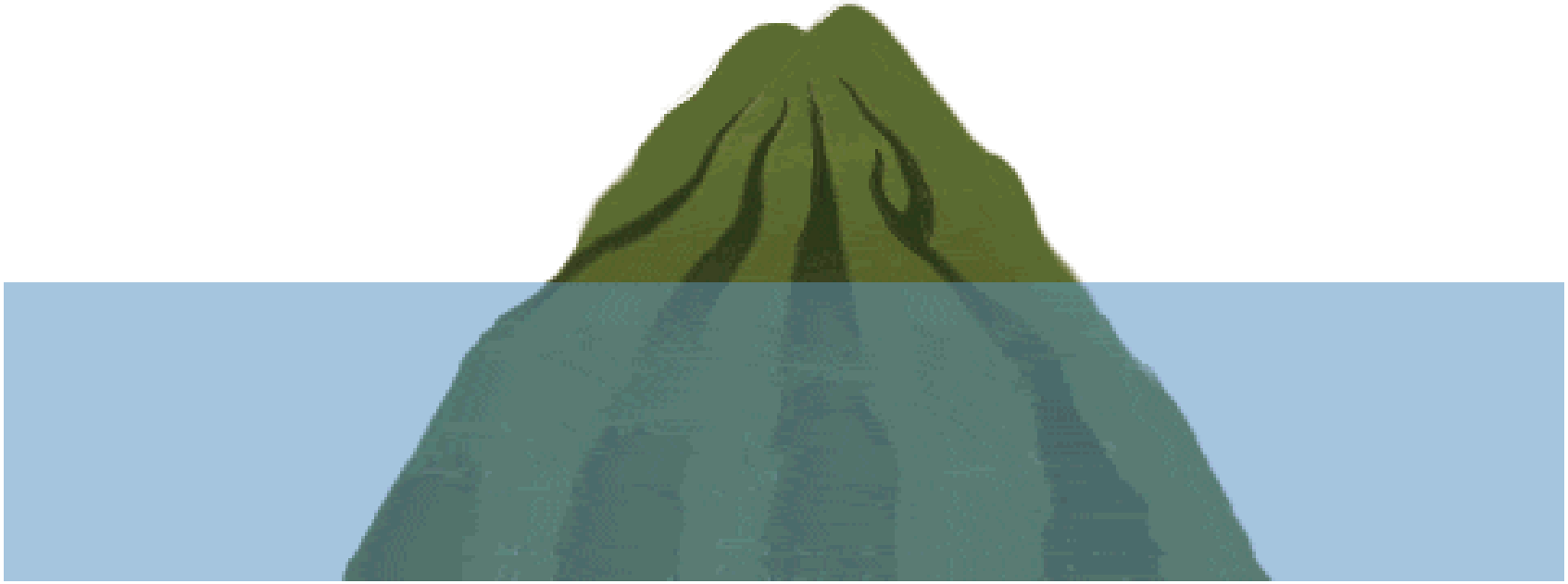
Paradox 1: coral reefs are rich ecosystems but are surrounded by oceans which lack nutrients

- **When aquatic organisms die, they tend to sink**
- **In the oceans, the nutrients they contain are therefore lost**
- **But in shallow water, like at coral reefs, these nutrients remain available**
- **Also, sponges can live in crevices in coral reefs, are filter feeders, and thus accrue nutrients to the reef**

Resolution of the second paradox

Paradox 2: coral can only live in shallow water but are often surrounded by deep water

- **The extant theory was that coral was a thin encrustation on top of volcanos just below the surface**
- **Darwin proposed that the volcano had to be slowly subsiding, and the coral kept up with the subsidence**
- **A reef would therefore start as a fringe reef, then become a barrier reef, then become an atoll reef**
- **The Great Barrier Reef is similar, except starting with a continental shelf**
- **When, many years later, it was found that the coral layers are often very deep, Darwin's theory was accepted**



Fringing reef (Cook Islands)

Barrier reef (Austral Islands)

Atoll reef (French Polynesia)

In passing, how does coral reproduce?

Asexually / cloning:

- **Budding – a new coral grows out of the side**
- **Pathogenesis – unfertilised eggs grow**

Sexually / spawning:

- **Simultaneous, mass release of eggs and sperm**
- **Once a year, at night, after a full moon in late Spring**
- **The larvae swim and eventually attach themselves to a hard surface (remember: coral is related to jellyfish)**
- **Coral are hermaphrodite**

4.
Parasitic cuckoo

The European cuckoo

The adult female:

1. **Internally incubates an egg for 24 hours**
2. **Finds a nest of a particular species**
3. **Lays a similarly looking egg**
4. **Removes one of the existing eggs**

The baby:

1. **Is blind**
2. **Ejects the other eggs with its back legs**
3. **Receives all the food from the warblers, etc**

Ejecting the other eggs

Continuing to be fed

The life-dinner principle

- **How clever of the mother cuckoo!**
- **How clever of the baby cuckoo!**
- **How stupid of the warblers, etc!**

Inequality of costs:

- **The warbler can afford to fail**
- **The baby cuckoo has to succeed**
- **As did its parents, and its parents' parents, and its parents', parents' parents, and so on**

How did all this come about?

Questions:

1. **How does the baby cuckoo know that it has to eject the other eggs?**
2. **How could all this possibly have arisen through 'mindless' natural selection?**

The same answer to both questions:

- **It doesn't know**
- **'Ejecting' as a behaviour must have a strong genetic component which has become prevalent over time**
- **A lot of baby cuckoos died in the process because those who don't eject typically die**

5.
Mule

What are species?

A species is a group of living organisms that interbreed and produce fertile offspring

[Complications:

- **Hybridisation**
- **Asexual reproduction]**

Mule (male donkey + female horse)

Hinny (female donkey + male horse)

Hebra (male horse + female zebra)

Zorse (female horse + male zebra)

Species-crosses are both uncommon and sterile

Across species:

1. **Mating doesn't usually happen**
2. **When mating does happen, live offspring don't often result**
3. **When live offspring do result, they are usually sterile**

The three points above are quite different phenomena and any one of them, if absolute, would result in species being reproductively isolated from each other. As a corollary, fertile hybrids would require none of the three points to have applied.

Mules and hinnies

We know why they are sterile:

- **Donkeys have 62 chromosomes**
- **Horses have 64 chromosomes**
- **So, mules and hinnies have 63 chromosomes**
- **So, because this is an odd number, they don’t have normal double-helix DNA**
- **So, it is not surprising that they cannot produce viable eggs/sperm**

Humanzees

- **Luckily, humans (46) and chimps (48) also have different numbers of chromosomes**
- **But cats and pigs have the same number (38)**
- **As do sheep and snails (54)**

A sheep-snail

Costasiella kuroshimae (a type of sea slug)

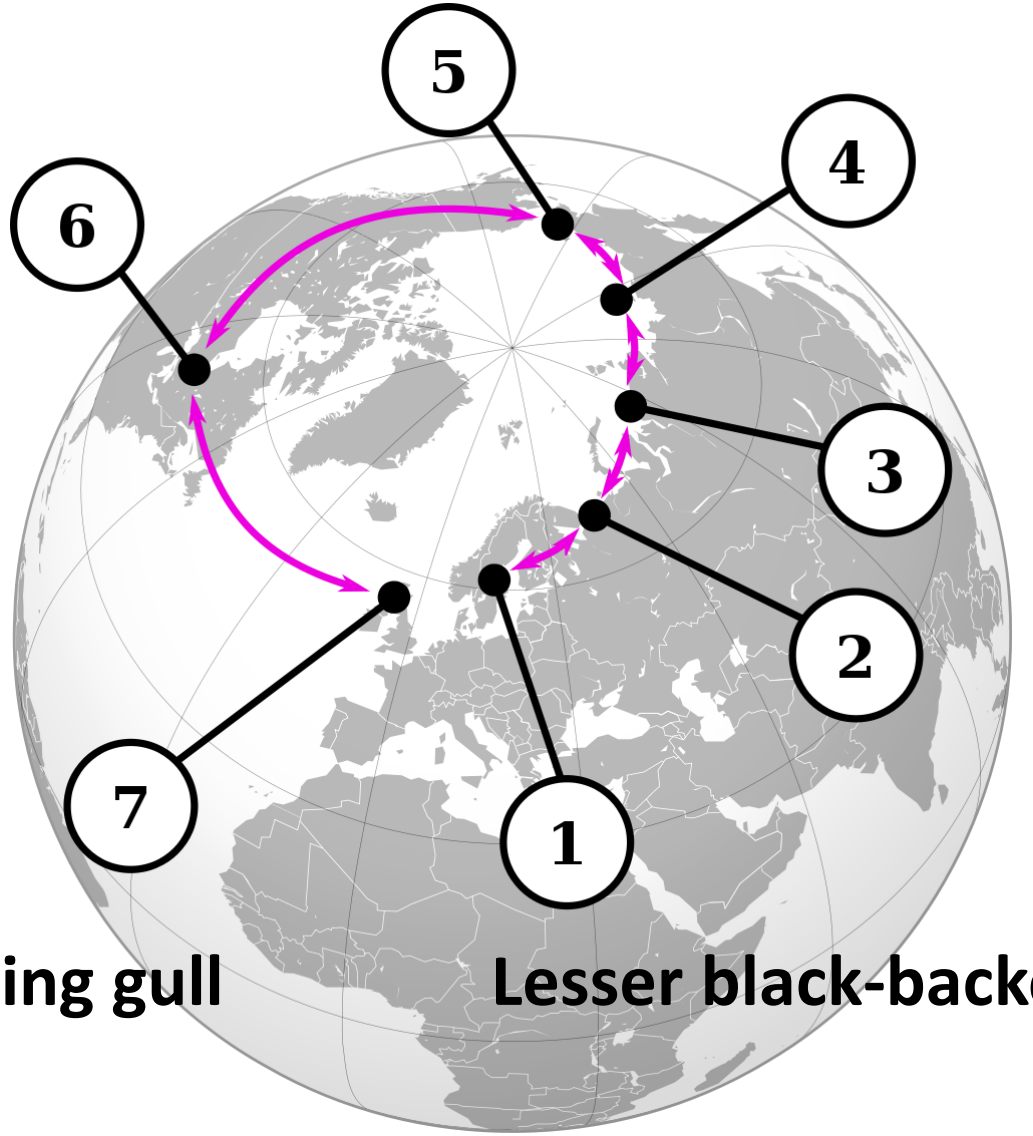
6.
Herring gull

Two species of gull

Herring gull (Larus argentatus)

Lesser black-backed gull (Larus fuscus)

How many species of gull?



Herring gull **Lesser black-backed gull**

How the two species inter-breed

- **Herring gulls and less black-backed gulls both nest in the UK. They look different and they don't inter-breed. Just like other distinct species.**
- **But follow the herring gulls westwards and they look less and less like the UK herring gulls and more and more like the UK black-backed gulls.**
- **Until, back in the UK, they are the black-backed gulls!**

The two gulls are a ring species

- **This is a ring species**
- **Throughout the whole of the ring, excepting the one point, the gulls are sufficiently similar to their neighbours to inter-breed but, at one point in the circle, they don't.**
- **It can only happen if there is a big barrier in the middle of the ring.**
- **The theory goes that one of the species started out in the UK, gradually moved westwards or eastwards, evolving as it went, until it got back to the UK in changed form**

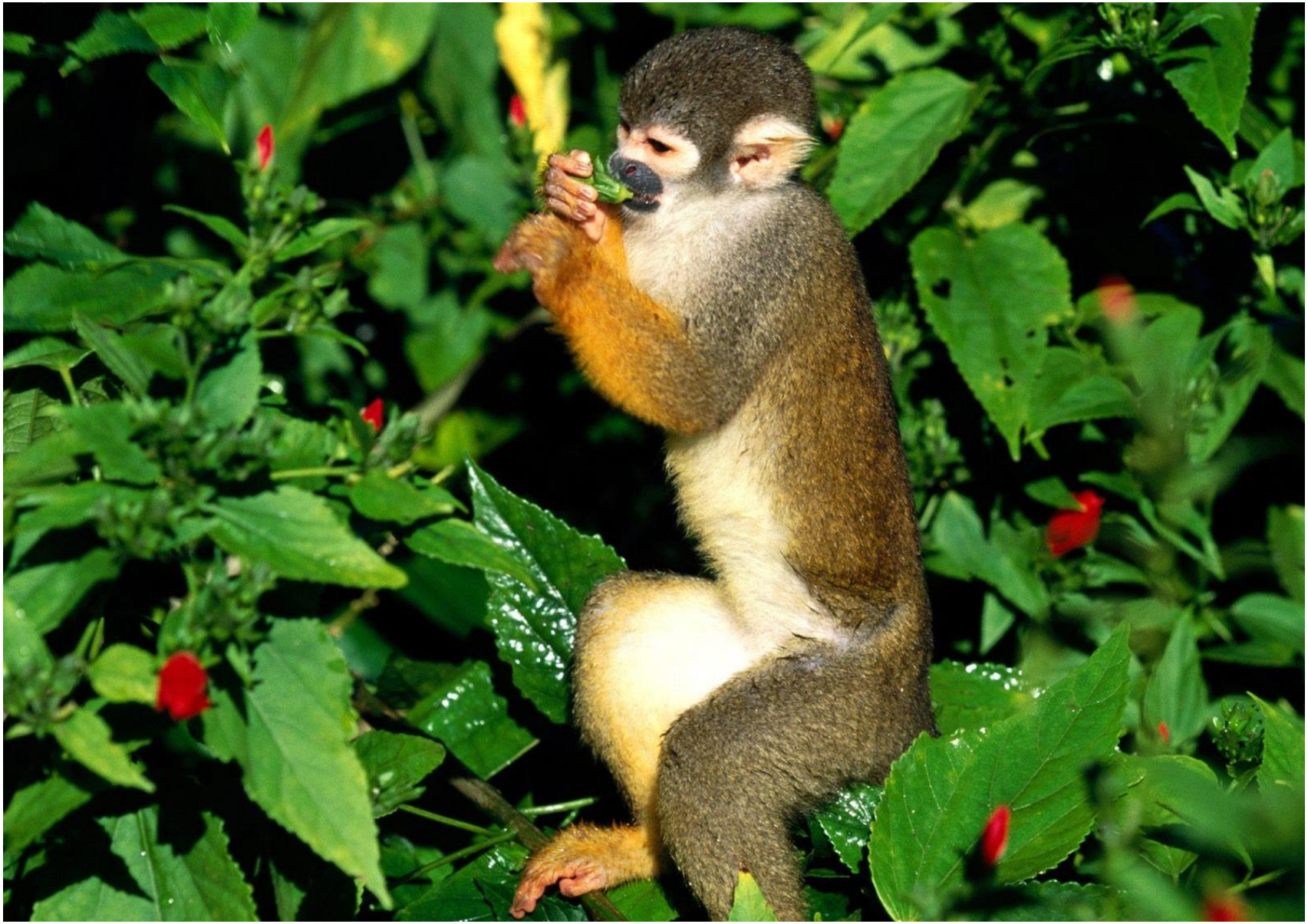
Other ring species

Ditto:

- **A salamander in California (mountains round a plain)**
- **A sparrow in California (plains round a mountain range)**
- **A warbler in Asia (Himalayas)**
- **A spurge (Caribbean sea)**

7.
Squirrel monkey

Can this monkey see red fruit?



Mammals and seeing in colour

- **Most mammals have poor colour vision compared with birds, reptiles, etc**
- **It is thought that this is because mammals started off as creatures of the night and therefore prioritised volume of light over its colour**
- **Indeed, most mammals only see in black-and-white or, at best, are red-green colour blind**
- **The exceptions are primates and marsupials, who have each re-developed trichromacy**

Trichromacy

- **Trichromats, like us, have 3 kinds of cones ('R, G & B') which are compared to judge colours**
- **(Turtles are apparently tetrachromats)**
- **The cones are made of proteins (opsins) whose production is, in turn, controlled by genes**
- **So, trichromats have 3 genes ('R, G & B') which allow them to see in colour**

Colour blindness

- **Someone is blind to a colour if they don't have any working genes for that colour**
- **For most genes, you have two copies of the gene**
- **So, people can't see blue if and only if both of their blue genes don't work**
- **But the red and green genes are on the X chromosome, which males (but not females) only have one copy of**
- **So, males can't see red (or green) if their single red (or green) gene doesn't work**
- **That is why men are much more likely to be red-green colour blind than women**

Dichromacy and monochromacy

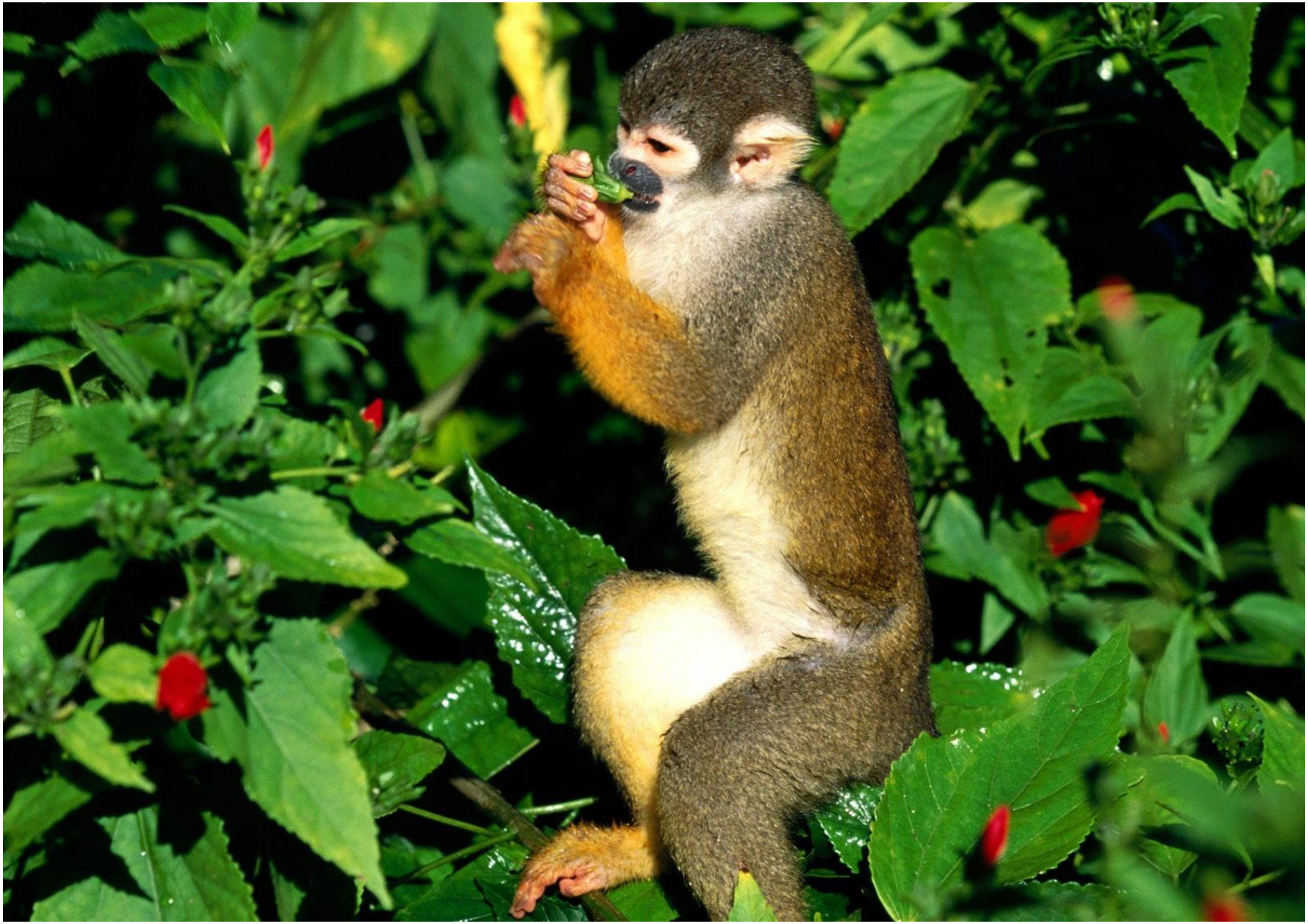
- **Dichromats, like most mammals, have two kinds of cones ('R & B')**
- **The spectrums of light stimulated by R and G cones overlap, so mammals can see everything but they can't distinguish between R and G**
- **Monochromats, like seals and whales, only have B cones. As well as only seeing in black and white, red and green things look dark to them.**

Some New World monkeys

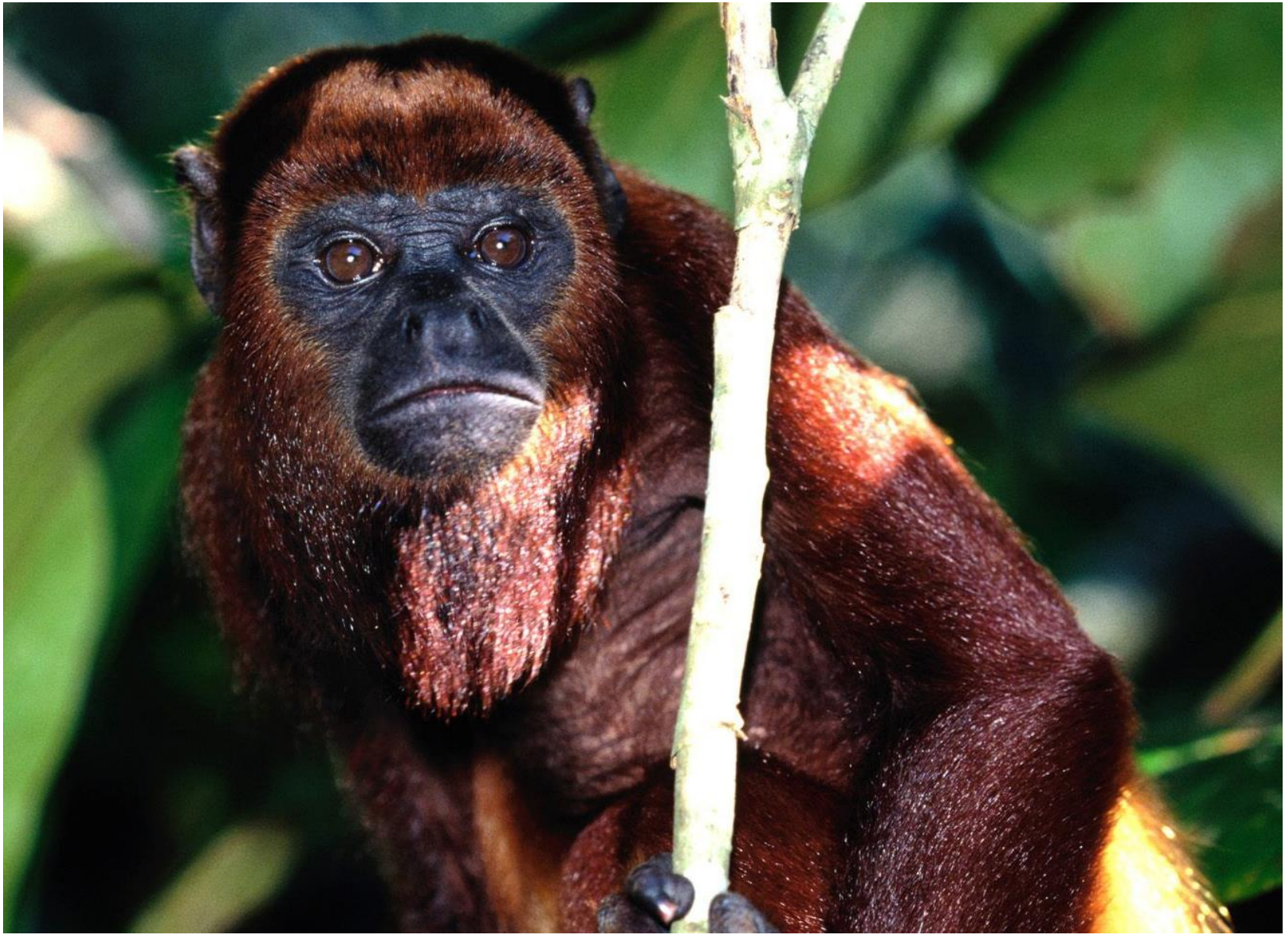
- **Night/owl monkey**
- **Squirrel monkey**
- **Howler monkey**

Night/owl monkey (monchromatic)

Squirrel monkey (mostly dichromatic)



Howler monkey (trichromatic)



Night/owl monkey (monchromatic)

- **Not surprisingly, night/owl monkeys are nocturnal (the only nocturnal monkeys)**

The squirrel monkey's tale

- **Squirrel monkeys have two genes ('R & B') but the 'red gene' can be either the R or the G 'allele' (aka version)**
- **So, all male squirrel monkeys are dichromatic, but in two different ways**
- **Whilst, some (around half) female squirrel monkeys are trichromatic**
- **This is called polymorphism (two versions of a gene continue to exist)**

Polymorphism

Why doesn't one of the versions of the gene go extinct?

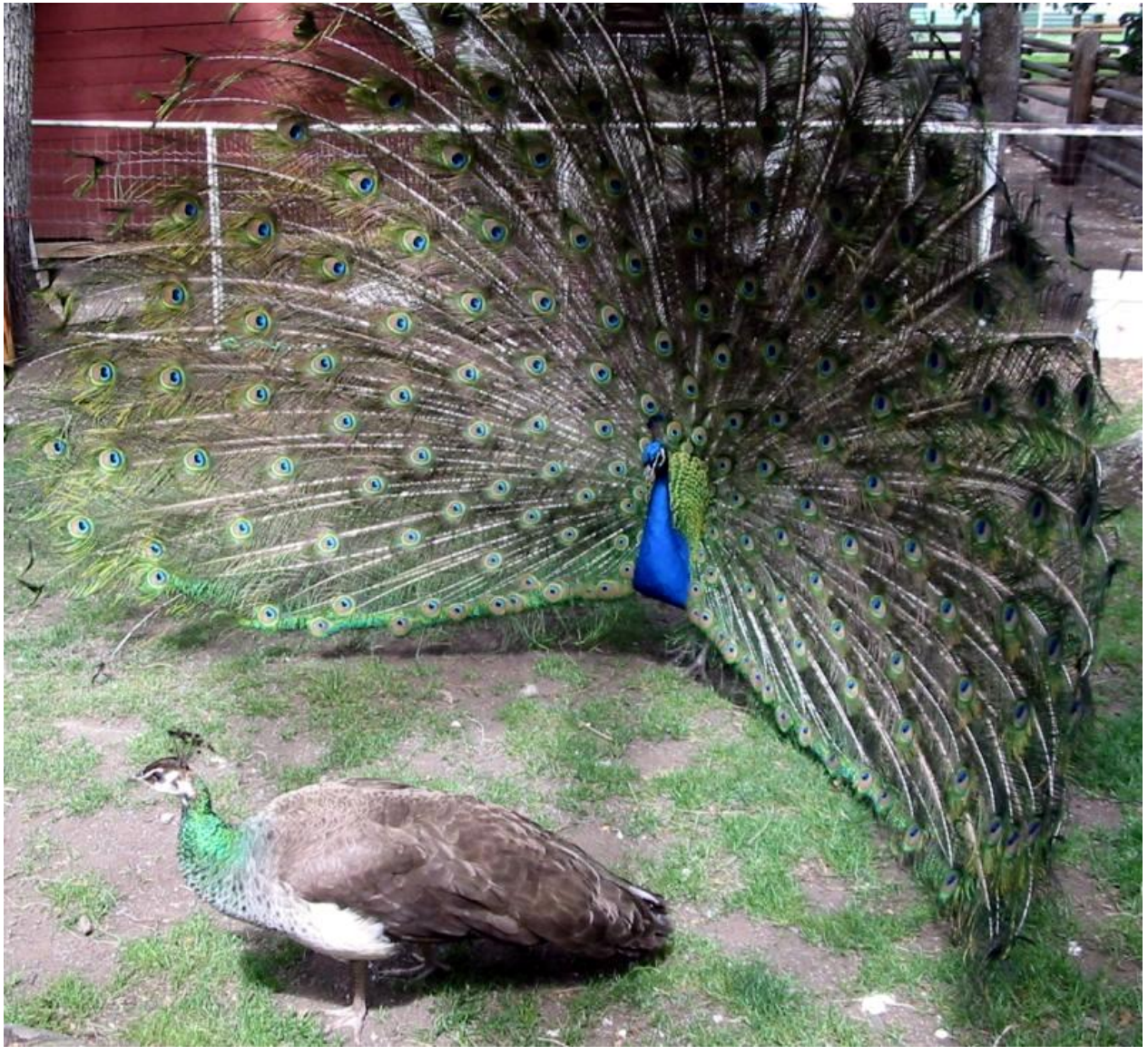
- **Possibility 1 - frequency-dependent selection: whichever male type is rarer has an advantage (e.g. one male can see red fruit, the other green fruit)**
- **Possibility 2 – heterozygous advantage: the trichromatic females have an advantage (cf. sickle cell anaemia and malaria)**

Howler monkeys

- **Howler monkeys have an R gene and a G gene as well as a B gene**
- **So, they are trichromatic**
- **But their genes are in different places than those for other trichromatic primates**
- **So, it appears that they used to be like squirrel monkeys but then re-discovered trichromacy**

8.
Peafowl / peacock

Why do peacocks have such massive, decorated tails? (It clearly isn't natural selection because the tail serves no utilitarian purpose)



Darwin's answer

- **Because peahens happen to like their males to have massive, decorated tails**
- **Peahens choose who they mate with**
- **So, those males with massive, decorated tails get chosen more often and have more offspring**

Darwin called this 'sexual selection'

R.A. Fisher's formalisation of sexual selection in the 1930s

- **Some females happen to prefer ornament X**
- **So males with ornament X prosper**
- **Males with ornament X are likely to have had a father who had ornament X**
- **The father was chosen by the mother so the mother is likely to have liked ornament X**
- **So, the male with ornament X is likely to have the genes for liking ornament X as well as the genes for ornament X itself**
- **Ditto the females who like ornament X**
- **So females who like ornament X prosper**

R.A. Fisher's formalisation of sexual selection in the 1930s (cont)

- **If the female preference for ornament X is for a more prominent X than the males typically have, ornament X will become more and more prominent until its tangible (i.e. natural selection) disadvantages equal its attractiveness (i.e. sexual selection) advantages**

Long-tailed widowbird - female

Long-tailed widowbird – non-breeding male

Long-tailed widowbird – breeding male

Long-tailed widowbird

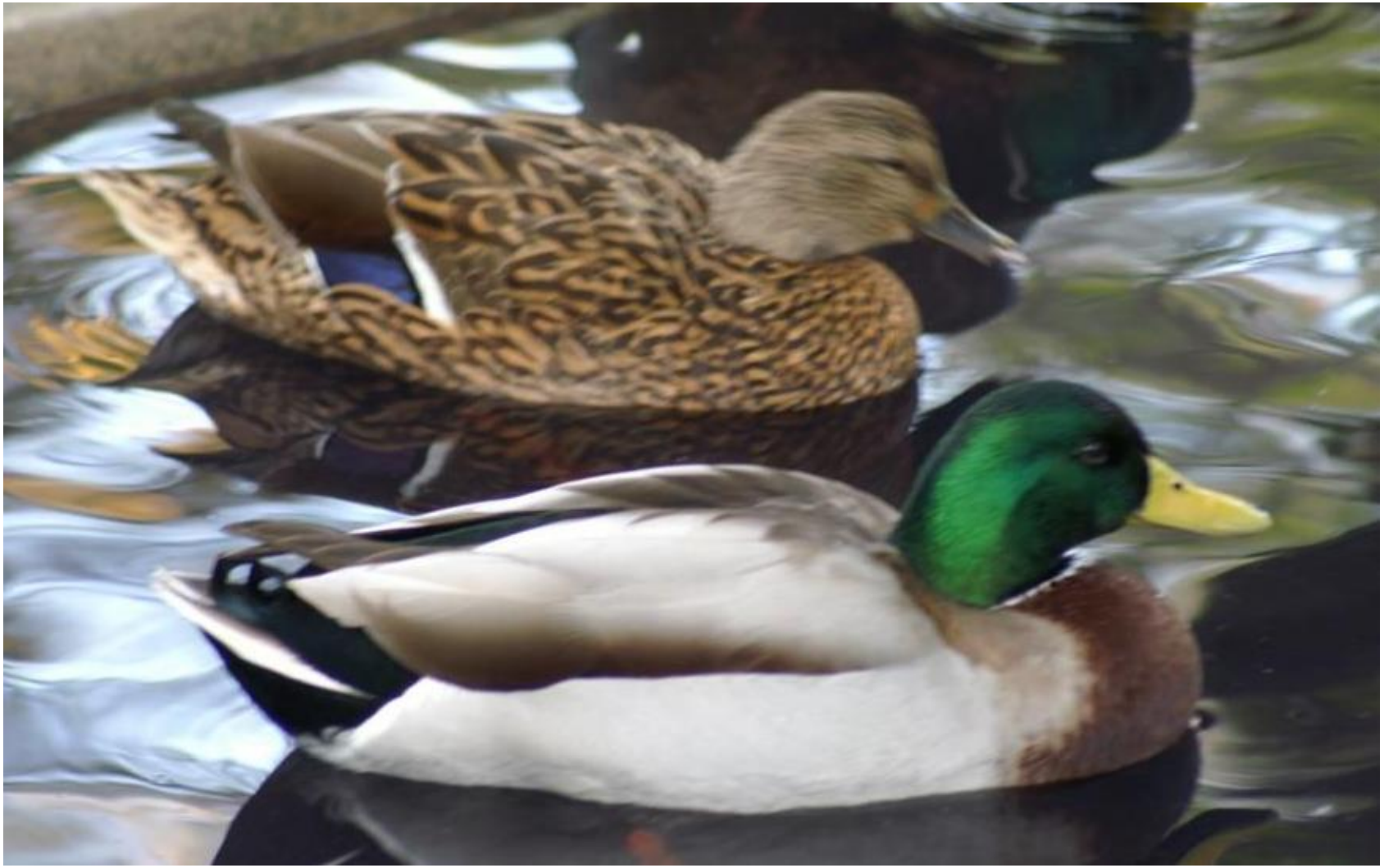
- **Some bloke captured 36 male long-tailed widowbird. He cut off the tails of 12 and glued these tailed onto the tails of 12 of the others. So he had 12 artificially short-tailed, 12 normal long-tailed and 12 super long-tailed.**
- **Males are territorial, so he could count how many nests each one 'owned'**

Long-tailed widowbird (cont)

- **The super long-tailed were the most successful, then the normal long-tailed and then the short-tailed**

- **So, not only did the females prefer long tails but they preferred even longer tails than those which naturally, currently occur**

Male and female birds often look different



Male and female birds often look different

King parrots

Rainbow lorikeets

The male/female differences amongst birds are greater than just looks

- **The male/female differences amongst birds can take many different forms:**
  - **Song (e.g. canaries)**
  - **Behaviours (e.g. bowerbird)**
  - **Bright colours (e.g. ducks)**
  - **Tails (e.g. the long-tailed widowbird)**
  - **Ornaments (e.g. peafowl)**
- **In most cases, it is the male who has the bright colours, sings, prances around, has a long tail, etc**
- **And in most cases, it is the female who is basically choosing who their mate is**

Ditto other animals

- **Frogs: males sing; females are usually mute**
- **Cicada: males sing; females are mute**
- **Mandrills: it is the males who have the brightly coloured bottoms and noses**

In most cases, it is the females who are basically doing the choosing (with the males happy with any mate)

- **Humans: it is mostly the females who dress up**

9.
Honey bee

Colonies and the caste system

A division of roles within a colony ('eusociality'):

- **One queen, who lives up to 8 years**
- **A few male drones, who live until they mate**
- **Thousands of female workers, who live a few months:**
  - **Child rearing, when young**
  - **Colony maintenance, when middle aged**
  - **Foraging, when seniors**

The female workers are:

- **Genetically identical to the queen (cf. royal jelly)**
- **Voluntarily sterile**

This is the same setup as for ants (to which they are closely related)

Why do bees work as part of a colony?

- **For unusual genetic reasons, bees (which are nearly all female) are more closely related to their sisters than they to their (hypothetical) daughters**
- **So, in terms of passing on their genes, it is more effective for an bee to help raise sisters than to have daughters**
- **So, they choose to work in a colony and to be sterile**

Why are these unusual genetic reasons?

- **Too difficult to explain in this talk**
- **See my ant talk**
- **Male bees have only half the genes of female bees**
- **Fathers therefore pass on the entirety of their genes to their daughters**
- **Females bees with the same father are therefore very closely related**
- **Google ‘haplodiploid’**

Being a colony allows complex behaviours

- **Builders of hives, honeycombs and cells**
- **Thermoregulation of the hive: fanning to cool or vigorous wing flapping to heat**
- **The bee dance: the angle of the dance indicates direction and the extent of the waggles indicate distance**
- **Makers of food and other products**

What do bees make and eat?

What do they make?

- **Honey: repeatedly regurgitated and ingested nectar**
- **Beeswax: a waxy secretion from glands, made mainly from honey**
- **Propolis (aka bee glue): beeswax + plant resins**
- **Royal jelly: a milky secretion from glands, made mainly from pollen**
- **Bee bread: pollen + honey + salivary enzymes**

What do they eat?

- **Royal jelly (young larvae only)**
- **Honey (and thus nectar) for carbohydrates (all ages)**
- **Bee bread (and thus pollen) for protein (larvae and youngsters only)**

Some complex behaviours of ants

- **Arable farming: feed leaves to fungus, which they later eat**
- **Pastoral farming: guard aphids, who they milk for their honeydew**
- **Builders: of nests, with many chambers and multiple floors**
- **Slave makers: of other ants**
- **Pantries (honeypot ants)**

Honey bee cells

Integrated hexagonals are the best possible shape for holding the most honey with the least amount of wax

Honey bee cells

Darwin pointed out:

- **Across bee species, there is the full range from separate, irregular, cells to integrated, hexagonal cells**
- **Some make circular cells by turning around on a spot**
- **Others make circular cells but with flat edges where they would otherwise intrude on another cell**
- **The flat edges are then chewed away such that they are single, rather than double, layer (thus saving wax)**
- **If a full and regularly spaced set of circular cells is done at the same time this way, then the end result will be hexagonals**

Honey bee cells (cont)

He therefore undertook a number of experiments using coloured wax, etc

The result: as he predicted, a full and regularly spaced set of circular cells is created at the same time, with flat edges where these meet and with the excess wax chewed away, the end result being hexagonals

Honey bee cells (cont)

He then went on to argue:

- **Producing a pound of wax requires the bees to consume around 15 pounds of sugar, which equates to a lot of nectar.**
- **Furthermore, whilst some bees are secreting the wax, the others have to hang around idly**
- **So, the more efficiently the wax is used, the more that group of bees will prosper**
- **So, over time, wax usage will become more and more efficient, so long as the efficiency gains can be made by bees doing the sorts of things that bees can do (turn around, chew, etc)**
- **So, over time, the instincts of the bees that prosper results in hexagonal honey cells**

10.
Naked mole rat

Naked mole rats

Like termites:

- **Live in colonies with a single queen and 1-3 kings**
- **The rest are voluntarily sterile, both workers and soldiers**

In this case, the how and why is known:

- **The queen kills/maims any other female who becomes pregnant and/or any children that are born**
- **Ditto meerkats (but they sometimes run away)**

Naked mole rats

- Live underground in tunnel systems
- Are up to 10cm long
- Have their front teeth outside of their mouth
- Eat their own faeces
- Do not regulate their body temperature
- Do not feel pain
- Never get cancer

‘Vertebrate of the Year’ in 2013!

The agenda

1. Axolotl
2. Coral
3. Earthworm
4. Cuckoo
5. Mule
6. Herring gull
7. Squirrel monkey
8. Peacock
9. Honey bee
10. Naked mole rat

A. Locust
B. Flatfish