How did Warm-Blooded animals evolve from Cold-Blooded ones?

And When …… and Why??

Its complicated…..

Definitions

Warm-blooded animals maintain internal body T° within a narrow range which can differ significantly from ambient T° using metabolic & other means

Cold-blooded animals can modify internal body T° higher/lower than ambient but over wider range, by enhancing metabolic effects with behavioural and anatomical adaptations

Some background

Birds and Mammals are the archetypal "warm-blooded" [endothermic] vertebrates
Both evolved from LAND reptiles (synapsids = mammals, theropod dinosaurs = birds) that may ALSO have been endotherms

Fish, amphibians & reptiles are the archetypal "cold-blooded" [ectothermic] vertebrates

And **all invertebrates** are "cold-blooded" [ectothermic]

Therefore the **"WHEN"** is before 66 million years ago (66 mya) – i.e. BEFORE extinction of dinosaurs

mammals probably evolved 225 mya

How did Warm-Blooded animals evolve from Cold-Blooded ones?

WHY (bother)?

Suggested reasons include

Habitat exploitation – including becoming nocturnal – i.e. when too cold for ectotherms [such as predatory dinosaurs] to be active

Food exploitation – digestion uses enzymes which work faster/more efficiently with inc T° *(within limits!)*

Higher Metabolic Rate (BMR = Basal Metabolic Rate – the amount of E needed for all bodily functions when at rest)
- more efficient digestion of wide range foods
- quicker response = quicker capture of prey, or evasion of predator
- fight infection (bacterial, viral, parasitic)

Parental care (mammals & birds nurture young, fish, amphibians & reptiles less so)
- young that are cared for can be produced in smaller numbers but of larger size & greater developmental maturity so favouring survival

Being cold blooded can't be SUCH a disadvantage ....

Estimated Number of species

Mammals : 5500
Birds : 11000
16500

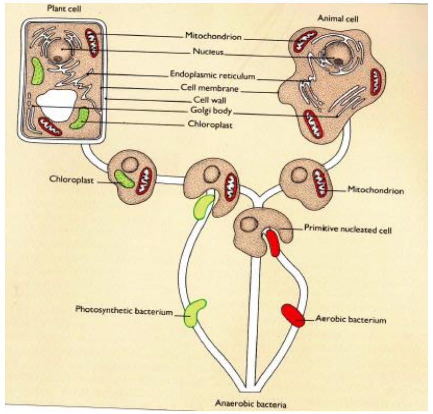
Fish : 34000
Reptiles : 11000
Amphibians : 8000
53000

How did Warm-Blooded animals evolve from Cold-Blooded ones?

How

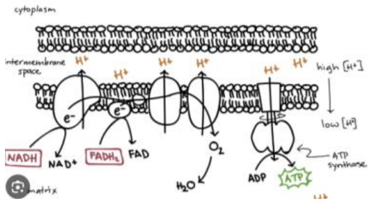
Back to the beginning …….

Mitochondria originated as FREE LIVING aerobic bacteria-like organisms.
Chloroplasts originated as FREE LIVING photosynthesising bacteria-like organisms.
Explains why they have their own DNA!

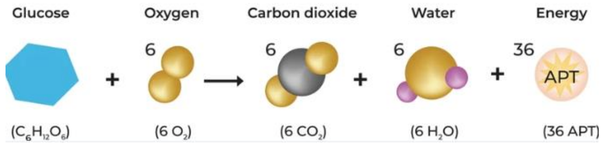


3-D image of "typical eukaryote cell"

Mitochondria house the chemicals used for generating **ATP (Adenosine Triphosphate)** the molecule used for energy in **EVERY CELL** – ie "metabolism".



OR, more simply put



So ALL living things generate [some] heat including plants

Eastern Skunk Cabbage
– can melt snow locally to ensure early blooming – **inside flower can be 22°C**

Sacred Lotus can reach **30 -36°C;**
Voodoo Lily & **Titan Arum** increase flower T° to aid scent dispersal

How did Warm-Blooded animals evolve from Cold-Blooded ones?

Endotherms create AND retain heat

Heat creation / dissipation *(viz mammals)*

Metabolism

Brown Adipose Tissue [BAT] in placental mammals
lots of mitochondria, uniquely with uncoupling protein 1, [UCP1].
Enables metabolic thermogenesis without creating ATP

Shivering *(repeated contraction & relaxation of skeletal muscles, WITHOUT moving limb / body part - resulting in by-product of heat with minimal E consumption*

Behaviour *(sunbathe, sweat [primates & horses], avoid cold, hibernate / torpor)*

Dissipating excess heat *also essential – being aquatic avoids over heating, as water much better conductor of heat than air*

Heat Retention

Insulation *(fat layer, hair, feathers)*

Behaviour *(inc hibernation – relies on BAT and UCP1)*

Thermogenesis in birds isn't (apparently) **as well studied**. They apparently do NOT have **BAT**. Thermogenesis is reported to be related to their pectoral muscles, which are used in flapping flight.

This doesn't explain PENGUINS!!

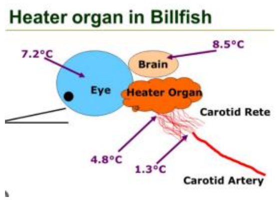
Endothermic animals can generate more heat than ectothermic ones, more consistently and RETAIN more heat. They also USE this heat more efficiently. All these features are advantageous – but come at a cost – notably **need for food!**

Ectotherms can survive in hostile environments, don't have to stay as cool as endotherms, eat less calories *(eg boa constrictor can weeks or months without food)*

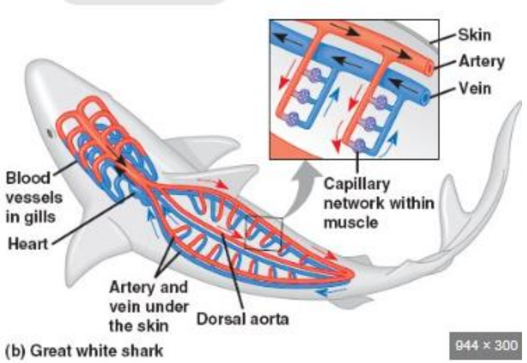
How did Warm-Blooded animals evolve from Cold-Blooded ones?

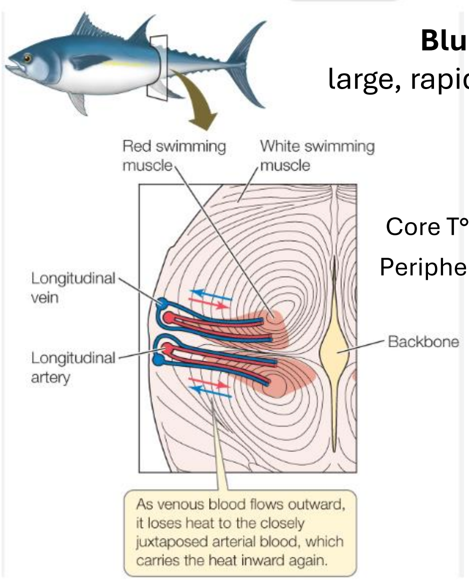
Ectotherms that maintain body/organ temperature above ambient

Sword fish and marlin have modified eye muscles that create heat rather than movement.
The increased warmth of the eye improves it's function



Great White Shark, uses counter current system *heat generated by active swimming muscles & metabolism warms venous blood as it returns to body's core and thereby warms major organs.*





Blue fin Tuna:
large, rapidly swimming fish

Core T° 31°C
Peripheral T° 21°C

Gigantothermy	Their massive size (up to 900 kg!) gives them a low surface area-to-volume ratio, helping retain body heat.
Insulating Fat Layer	A thick layer of **blubber-like fat** under the skin reduces heat loss.
Countercurrent Heat Exchange	Blood vessels in their flippers are arranged to conserve heat by warming incoming cold blood with outgoing warm blood.
Muscle Activity	Increased **flipper stroke frequency** in cold water generates internal heat [2].

In cold (sub polar) waters they can maintain a temp gradient of ~18°C between core & water

How did Warm-Blooded animals evolve from Cold-Blooded ones?

Temperature control options for land insects

REVIEW

Journal of Experimental Biology (2023) 226, jeb245751. doi:10.1242/jeb.245751

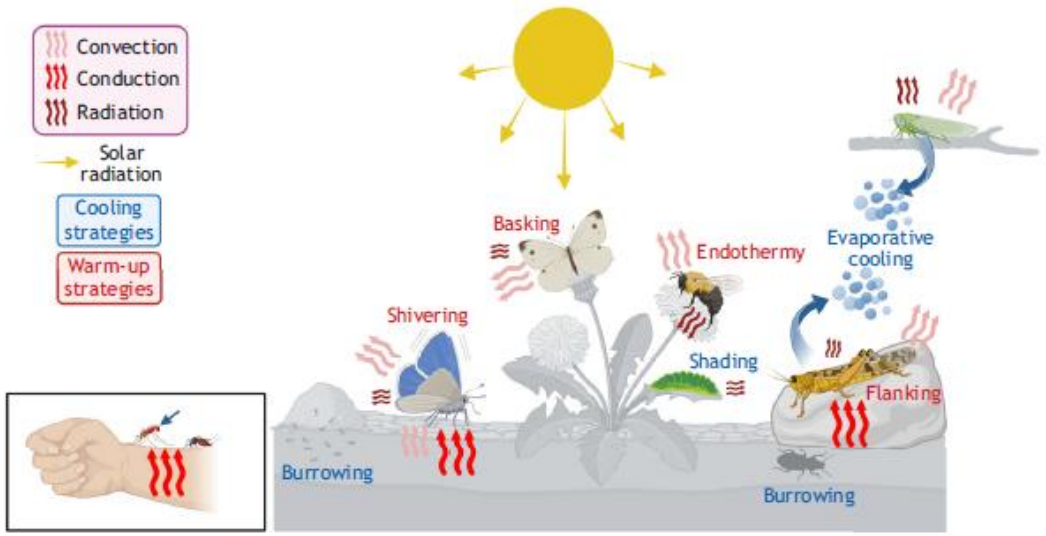


Fig. 1. Schematic representing examples of the major processes of heat exchange that occur between insects and their environment. These include convection (light pink arrows), conduction (red arrows), radiation (maroon arrows and yellow arrows) and evaporation (blue bubbles). Strategies to warm up (in red) or cool down (in blue) are also highlighted. Inset: strategies used by mosquitoes during blood feeding. *Anopheles* mosquitoes (inset, left) use evaporative cooling of urine and blood droplets (blue arrow) to reduce T_{abd}, while *Aedes* mosquitoes (inset, right) tend to have a T_{abd} closer to the temperature of the host and do not exhibit cooling mechanism while blood-feeding.

How did Warm-Blooded animals evolve from Cold-Blooded ones?

The Question was *How did endotherms (warm-blooded animals) evolve from ectotherms (cold-blooded animals)?*

The Answer (sort of) **is** *They didn't – they took a different route from them*

Thank you

References

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Legendre L.J. & Davesne, D. (f2020) The evolution mechanisms involved in vertebrate endothermy. Phil. Trans. R.Soc.B 375
Other internet sources

Spare text

The physiological importance of BAT, previously referred to as the 'hibernating gland,' is most strikingly observed in seasonal mammals, which require BAT's thermogenic properties to maintain body temperature during periods of hibernation or torpor, and to mediate periods of arousal and re-warming from these decreased metabolic states. Hibernation is a period of heterothermia, where body temperature may drop from 35–37°C to 0°C, accompanied by a period of metabolic reduction.[24] The onset of hibernation is often triggered by shortening daylight cues reaching the brain, in conjunction with the brain's own circadian rhythms. Torpor, on the other hand, is a short-term state of reduced physical activity and metabolism, and may be induced by reductions in environmental temperature or caloric restriction (or both).

Brown adipose tissue (BAT) mitochondria are distinct from their counterparts in other tissues in that ATP production is not their primary physiologic role. BAT mitochondria are equipped with a specialized protein known as uncoupling protein 1 (UCP1). UCP1 short-circuits the electron transport chain, allowing mitochondrial membrane potential to be transduced to heat, making BAT a tissue capable of altering energy expenditure and fuel metabolism in mammals without increasing physical activity. The recent discovery that adult humans have metabolically active BAT has rekindled an interest in this intriguing tissue, with the overarching aim of manipulating BAT function to augment energy expenditure as a countermeasure for obesity and the metabolic abnormalities it incurs. Subsequently, there has been heightened interest in quantifying BAT function and more specifically, determining UCP1-mediated thermogenesis in BAT specimens - including in those obtained from humans. In this article, BAT mitochondrial bioenergetics will be described and compared with more conventional mitochondria in other tissues. The biochemical methods typically used to quantify BAT mitochondrial function will also be discussed in terms of their specificity for assaying UCP1 mediated thermogenesis. Finally, recent data concerning BAT UCP1 function in humans will be described and discussed.

Uncoupling Protein 1

This unique protein is expressed exclusively on the inner mitochondrial membrane of brown and brite adipocytes and mediates the process of nonshivering thermogenesis. Oxidation of nutritional substrate is usually coupled to ATP generation through a series of electron transporters embedded in the inner mitochondrial membrane. UCP1 acts by uncoupling the process of substrate oxidation and ATP synthesis by allowing the protons to pass passively from the intermembrane space to the mitochondrial matrix through an alternative channel, dissipating the proton motive force without generation of ATP. Instead, the oxidized energy is released as heat

The Arctic ground squirrel hibernates over winter from early August to late April in adult females and from late September to early April for adult males,[15] at which time it can reduce its body temperatures from 37 °C (99 °F) to as little as −3 °C (27 °F).[16] During hibernation, its core body temperature reaches temperatures down to −2.9 °C (26.8 °F)[17] and its heart rate drops to about one beat per minute. Peripheral, colonic, and blood temperatures become subzero. The best theory as to why the squirrel's blood doesn't freeze is that the animal is able to cleanse their bodies of ice nucleators which are necessary for the development of ice crystals. In the absence of ice nucleators, body fluids can remain liquid while in supercooled state. This process is being studied with the hope that mechanism present in arctic ground squirrels may provide a path for better preservation of human organs for transplant.[18] The connections between brain cells also wither away in this state. The damage should have resulted in death, but research on related species show that these connections regrow after waking up. In the warmer months, the squirrel is active during the day.

two types of sweat glands can be found in humans: eccrine glands and apocrine glands.[2] The eccrine sweat glands are distributed over much of the body and are responsible for secreting the watery, brackish sweat most often triggered by excessive body temperature. Apocrine sweat glands are restricted to the armpits and a few other areas of the body and produce an odorless, oily, opaque secretion which then gains its characteristic odor from bacterial decomposition

TEWL =TransEpidermal Water Loss ~ 1li daily

•Honeybees: They warm up their flight muscles by contracting them without flapping their wings—a process called *shivering thermogenesis*. This allows them to fly even in cooler temperatures.
•Bumblebees: These insects can elevate their thorax temperature significantly above ambient levels during flight. Their ability to regulate heat is influenced by oxygen availability, which affects their metabolic rate.
•Certain moths: Like bumblebees, they use metabolic heat to warm up flight muscles before takeoff.
This ability gives facultative endotherms a survival edge in variable climates. They can remain active in cooler conditions without the constant energy cost of full-time endothermy.

Winged insects – simultaneous contraction of antagonistic flight muscles before or during flight aids warming up; also shivering – ie pre flight rapid contraction thoracic muscles, inc thoracic T – can be stabilised by circulatory system adaptations – different parts of body warmed to different amount – "blood" (haemolymph) can be moved from cooler abdo to warm thoracic