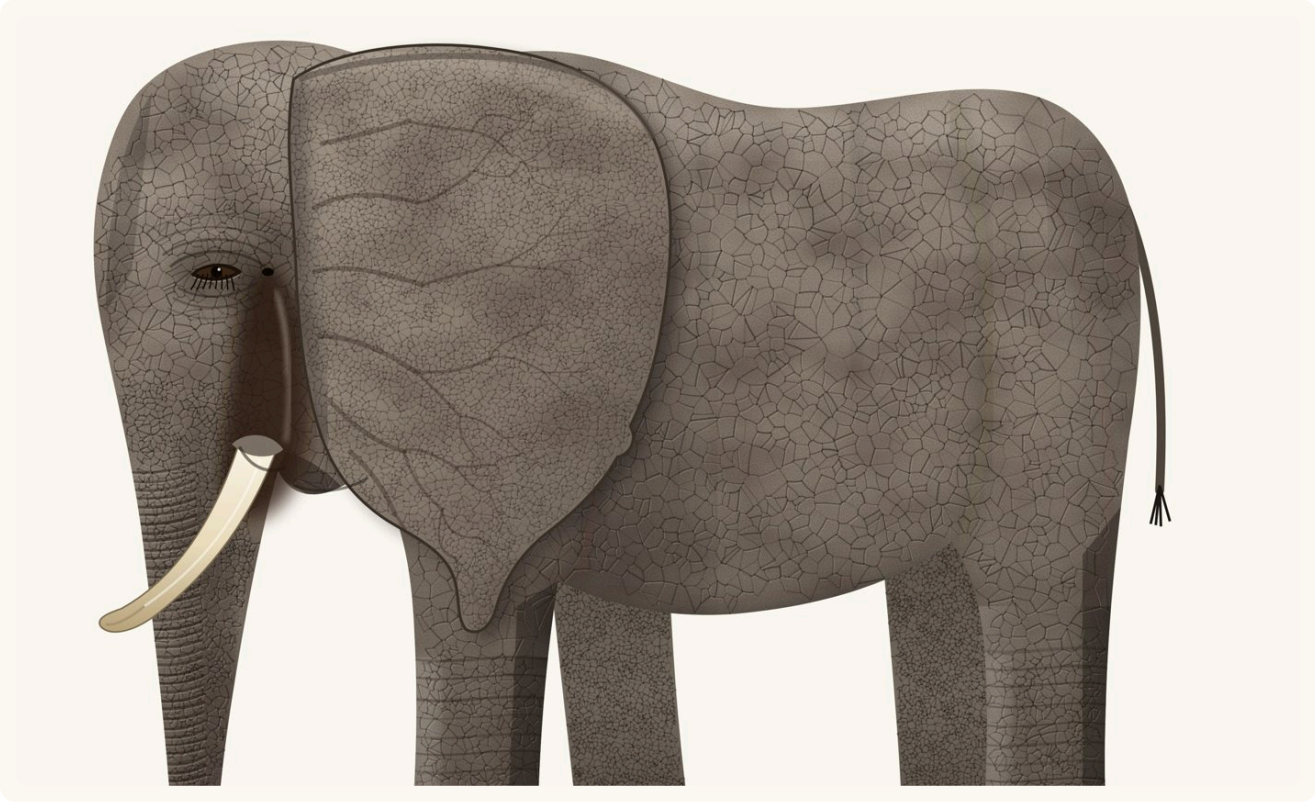
ELEPHANTS · PHYSIOLOGY & BEHAVIOUR

Temporal Glands, Sweating & Hormones in Elephants

Musth, temporin and chemical signals — and how a five-tonne animal keeps cool without sweat glands. With field notes for guides and a 15-question quiz.

SERIES **SAFARI NOTES** FORMAT **RESEARCH BRIEF & GUIDE NOTES** PUBLISHED BY **THE SAFARI SHOW**

> The temporal gland is found only in elephants, and the dark streak running down an elephant's cheek is one of the most misread signs in the bush. This brief covers what the gland is, who secretes and why, the hormones of musth, the chemistry of the message — and how an animal with no ordinary sweat glands keeps cool.



Key takeaways

- The **temporal gland is found only in elephants**. It sits on each side of the head, midway between the eye and the ear, and is a **modified apocrine sweat gland** — in effect the one place an elephant does something close to "sweating".
- Elephants have **no ordinary sweat glands** in their skin. They cool through their ears, water passing through the skin, cracked skin that holds water and mud, wallowing, hair and behaviour.
- **Musth** is a periodic state in mature bulls driven by a large rise in **testosterone**. Its visible signs are temporal gland secretion (TGS), constant urine dribbling, and aggressive, swaggering behaviour.
- **Hormones climb before the visible signs appear**, and cortisol tends to rise alongside testosterone in bulls that go into musth.
- In African elephants, **a streaming temporal gland on its own does not mean musth** — females, juveniles and even calves secrete, especially during excited social encounters.
- The secretion is a **chemical message**. In Asian bulls, a compound called **frontalin** becomes more prominent with age and acts as a pheromone that females near ovulation respond to most strongly.

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02 Who secretes, and why
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01 The temporal gland — what and where

Every elephant — African savanna, African forest and Asian — carries a pair of temporal glands, one on each side of the head in the hollow of the temple (the **temporal fossa**), roughly halfway between the eye and the ear opening. **No other living mammal has one.** Anatomically it is a **modified apocrine sweat gland**: the same broad family of glands that produce scented secretions in other mammals, enlarged and specialised.

The gland is a lobed mass of secretory tissue wrapped in a connective-tissue capsule. Its lobules drain into a single central duct that opens through a small pore in the skin. When the gland is active, the fluid wells out of the pore and runs down the cheek, leaving the dark streak that guides learn to spot from a distance.

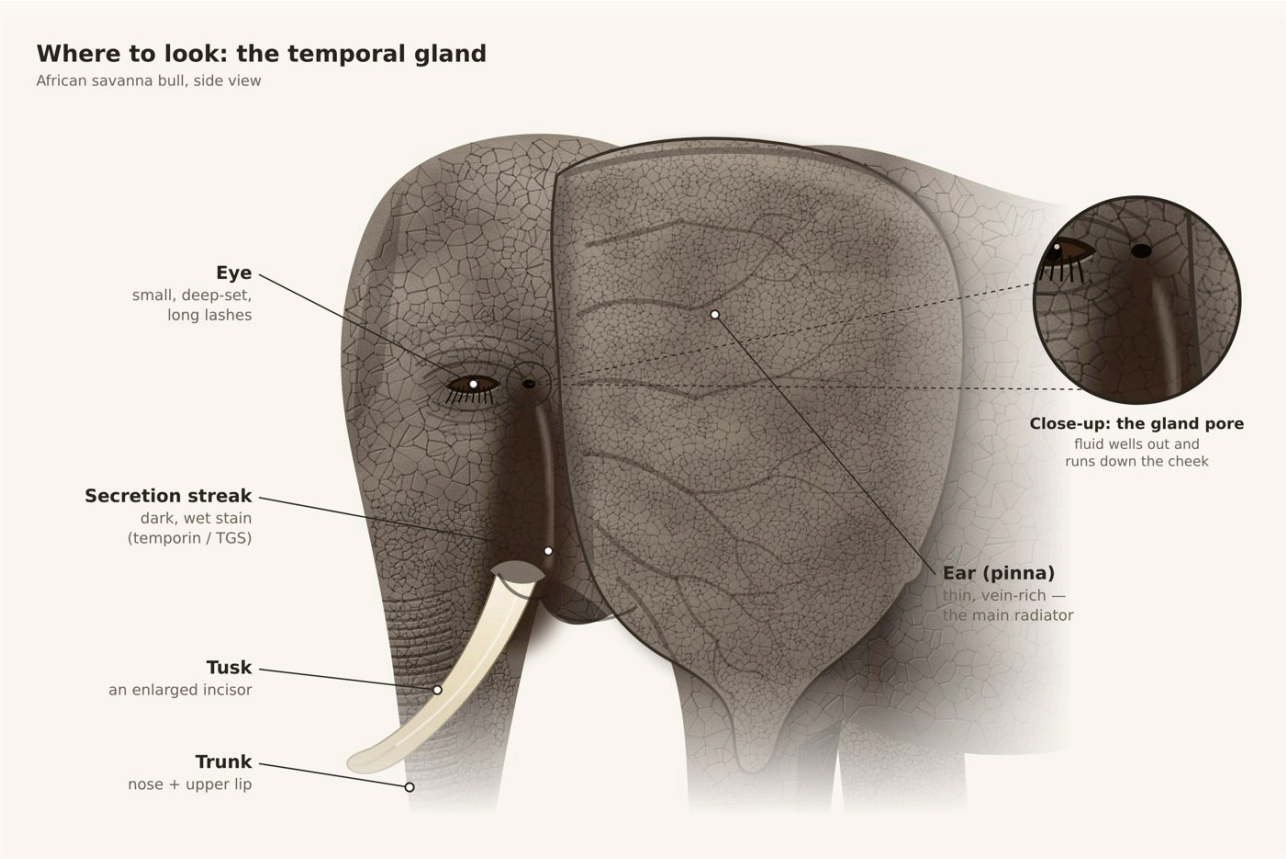


Figure 1. The temporal gland pore sits between the eye and the ear; in an active gland, a dark wet streak runs down the cheek.

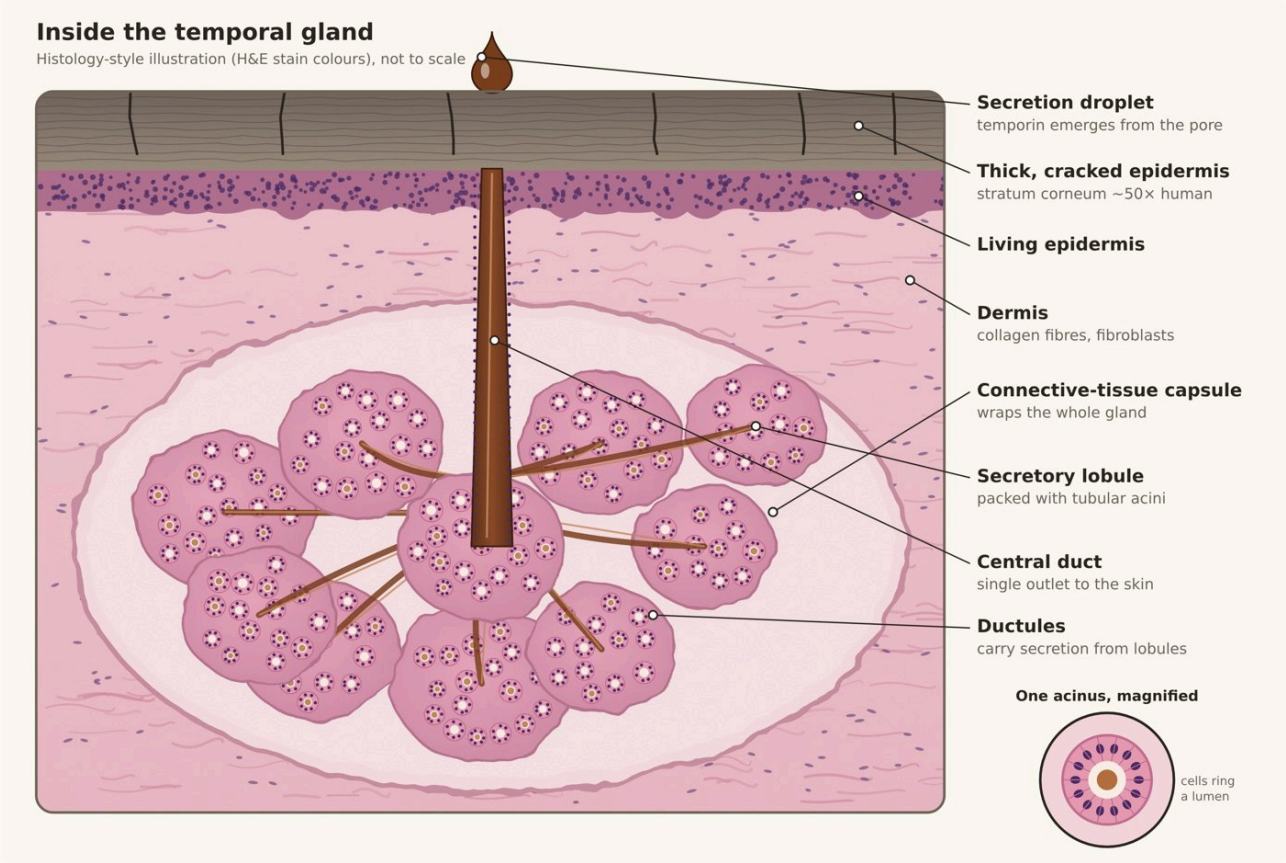


Figure 2. Inside the gland: secretory lobules of tubular acini drain through ductules into one central duct that opens on the skin. Colours follow a standard tissue stain.

The gland's size is not fixed. East African measurements on hundreds of elephants found wide variation in gland weight at any given age, and a combined left-and-right weight of **around 1.5 kg** was recorded in one active bull, whose secretion was a dark brownish paste. Researchers read that spread of weights as a sign that the gland goes through **cycles of secretory activity**, swelling when active.

WHAT COMES OUT

The secretion — called **temporin**, or simply **TGS** (temporal gland secretion) — is a complex mixture. It contains proteins, lipids (notably cholesterol), phenols, cresols and sesquiterpenes such as farnesol and related compounds. In bulls in musth it also carries high concentrations of testosterone (see Section 03) and a range of strong-smelling volatile compounds that humans can smell too.

02 Who secretes, and why

THE MOST IMPORTANT FACT FOR GUIDES

Temporal gland secretion is not the same thing as musth.

For decades this confusion delayed the discovery of musth in African elephants, because researchers saw females, juveniles and calves streaming from the temples and assumed the secretion meant nothing special.

MALES IN MUSTH

Heavy, sustained, dark

In mature bulls, heavy and sustained TGS is one of the three classic signs of musth, together with continuous urine dribbling and heightened aggression. The fluid is often thicker and darker, sometimes tar-like, and strongly scented.

FEMALES, JUVENILES & CALVES

Brief, social, frequent

African females secrete freely; Asian females tend to secrete mainly in late pregnancy or shortly after giving birth. Streaming often starts within seconds during greetings and reunions with loud rumbling and ear-flapping, and dries within about 10–15 minutes.

Sustained secretion in East Africa is more often seen when females are separated from family or disturbed, and more often in the dry season when families split into smaller groups. Two field studies, and the wider welfare literature, help frame what drives it:

- **Etosha, Namibia (1998):** secretion was not linked to predators, other herbivores or tourist vehicles, but it rose with how often family members displaced each other — pointing to **social interaction** as the main trigger.
- **Northern Tanzania** (Tarangire, Lake Manyara, Manyara Ranch): the chance of TGS rose with age, and females were more likely to show it than males. In larger groups females were less likely to secrete, while males were more likely to.
- **Not just stress:** welfare researchers note TGS appears across many arousal states, positive ones included, so it shouldn't be read automatically as distress. Patterns also differ by population — in **Gorongosa, Mozambique**, elephants of all ages and both sexes secrete in most seasons and group sizes.

03 Musth and its hormones

Musth (from an Urdu/Persian word for "intoxicated") has been known in Asian elephants for around 3,000 years but was only scientifically described in African elephants in **1981, by Joyce Poole and Cynthia Moss**

in Amboseli, Kenya. It is a periodic condition of mature bulls, and is normally a sign of a **healthy, well-conditioned male**. It is not the same as a seasonal rut in deer: each bull has his own timing, and in many populations bulls come into musth at different times of year.

THE HORMONE CASCADE

Like other mammals, elephants control testosterone through the **brain–pituitary–testes axis**: the hypothalamus signals the pituitary, the pituitary releases luteinising hormone (LH), and LH drives the testes to make testosterone. The adrenal glands, controlled through the same pituitary, make **cortisol**. During musth this system is turned up sharply. Unusually for a mammal, an elephant's **testes never descend**: they sit inside the abdomen, close to the kidneys.

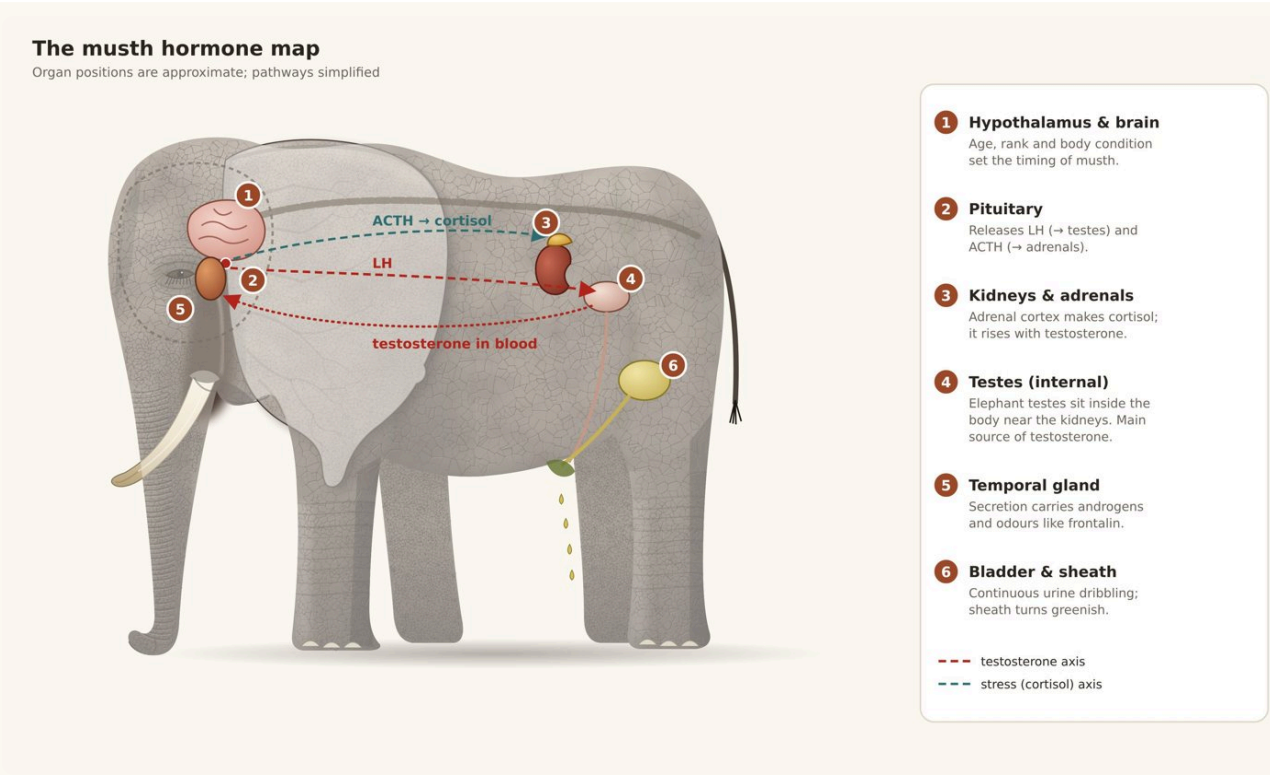


Figure 3. Where the musth hormones are made and where they act. The brain–pituitary–testes links are the general mammalian pattern; the cortisol link is documented in elephants.

HOW BIG IS THE SURGE?

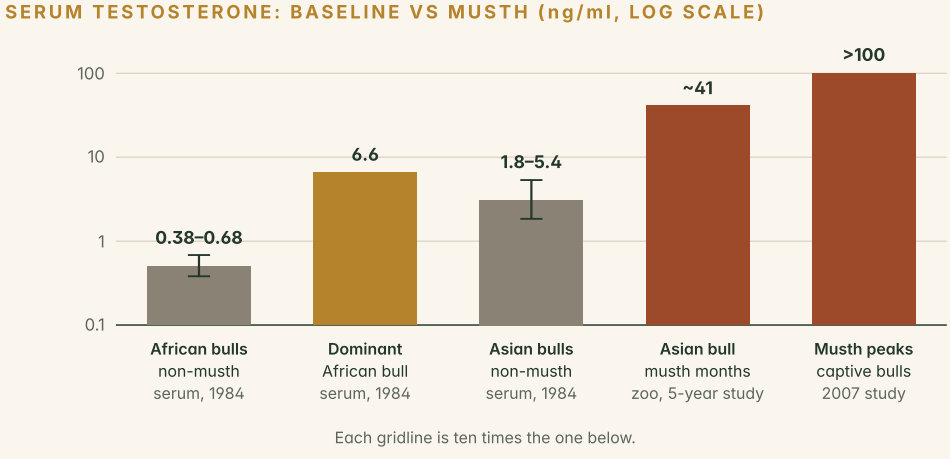


Figure 4. Serum testosterone in different groups, drawn from separate studies. Values illustrate the size of the change, not a single comparable dataset.

- A **1984 study** found non-musth African bulls had low serum testosterone (about 0.4–0.7 ng/ml), lower than non-musth Asian bulls (about 1.8–5.4 ng/ml). One dominant African bull stood out at 6.6 ng/ml.
- In a **five-year zoo study**, an Asian bull averaged about **41 ng/ml** during his musth months against about 7.6 ng/ml the rest of the year.
- A larger **2007 study** of captive African and Asian bulls found serum testosterone during musth often went **above 100 ng/ml**. Musth lasted on average almost three months, with no clear seasonality.
- The temporal gland secretion itself can be **far richer in androgens than blood**. The same 1984 study measured 78 ng/ml testosterone in the TGS of the dominant African bull and **547 ng/ml** in that of an Asian bull in musth.

HORMONES LEAD, BEHAVIOUR FOLLOWS

Following six wild bulls in **Kruger National Park** for 13 months through dung samples, researchers confirmed earlier zoo findings that **androgen levels usually rise before the physical signs of musth appear** — supporting the idea that the hormone change is what starts musth, rather than a consequence of it. The same work found seasonal effects on both androgens and stress hormones that varied with each bull's reproductive state.

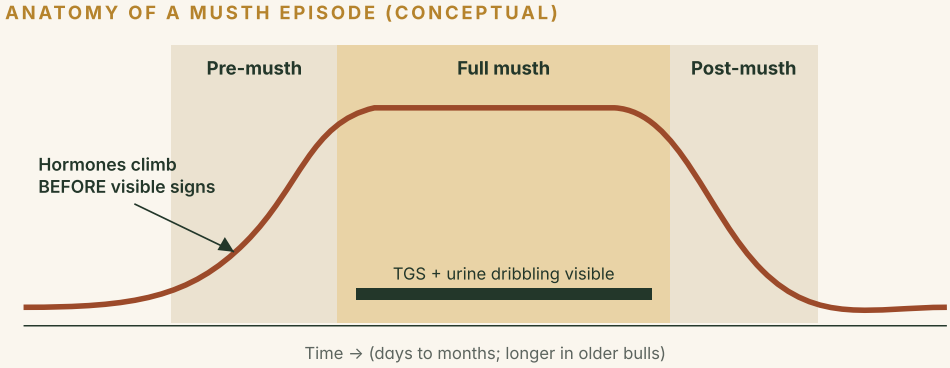


Figure 5. Conceptual shape of a musth episode. Asian-elephant handlers commonly split it into pre-musth, early, full and post-musth phases.

CORTISOL, THYROID AND DHT

- **Cortisol:** in the 2007 captive study, testosterone and cortisol rose together in almost every bull that showed musth, but not in bulls that didn't — suggesting the adrenal gland may help drive or support the musth state. A study on Asian bulls in Assam likewise found both hormones higher in the pre-musth state.
- **Not every adult bull goes into musth:** several physically mature captive bulls (mostly African) stayed at low testosterone and never showed real musth signs. Where bulls lived together, the oldest, most dominant male had the highest testosterone.
- **Thyroid:** overall testosterone and cortisol tended to rise with age while thyroid activity declined, with no clear thyroid–musth link in most bulls.
- **DHT:** dihydrotestosterone generally tracked testosterone in serum, but the dramatic musth spike in Asian bulls was not matched by a similar jump in DHT.

IS THE GLAND ITSELF MAKING HORMONES?

An electron-microscope study of the temporal gland in a musth Asian elephant reported that its cells looked built for steroid production — abundant mitochondria with tubular folds, many Golgi bodies and enlarged smooth endoplasmic reticulum, similar to testosterone-making cells in the testes and adrenal cortex. The

authors argued the gland may produce and secrete androgens itself. This is one study's interpretation; **the testes remain the main source of circulating testosterone**.

READING HORMONES WITHOUT TOUCHING THE ELEPHANT

Wild bulls can't be bled regularly, so researchers measure hormone breakdown products in dung and urine. A key marker is **epiandrosterone**, a testosterone metabolite that rises clearly in musth. Remarkably, **tusks also lay down testosterone in their growth layers**: a 2023 study found yearly testosterone surges up to ten times baseline in a woolly mammoth tusk, matching musth peaks in a modern African bull's tusk — direct evidence that mammoths had musth too.

04 Musth, age and elephant society

Young males leave their families at puberty, around **12–15 years old**. In Amboseli, bulls first came into musth at an average age of **about 29**. Early episodes are short — days or weeks — and lengthen with age; a bull in his forties typically stays in musth for **two to four months**, often at a similar time each year. Musth generally continues until bulls are in their mid-fifties to sixties.

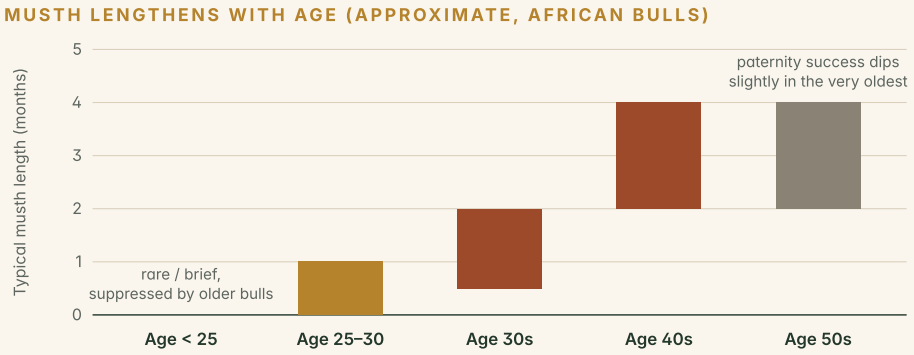


Figure 6. Approximate musth duration by age in African bulls, based on long-term Amboseli observations.

Musth lets a bull **punch above his weight**: a smaller musth male can dominate larger bulls who are not in musth. Genetic paternity testing of **119 Amboseli calves** born over 22 years showed that both age and musth boosted a male's chances of fathering calves, with success climbing with age until dipping slightly in the very oldest bulls. Yet bulls of all ages, in and out of musth, sired calves.

THE PILANESBERG LESSON

In South Africa's Pilanesberg, young orphaned bulls translocated without older males entered unusually early and long musth and **killed many rhinos**. When six full-grown bulls were introduced in 1998, the young bulls' musth became brief and the rhino killings stopped. Younger males are known to lose musth signs within hours, or even minutes, of being threatened by a higher-ranking musth bull. **Older bulls are, in effect, a hormonal brake on the young.**

05 The chemistry of the message

Temporal gland secretion is a **broadcast**. Elephants investigate it with the trunk tip and transfer it to the mouth, where the **vomeronasal (Jacobson's) organ** in the roof of the mouth picks up chemical signals — a behaviour similar to the "flehmen" of other mammals.

- **Frontalin** is a small bicyclic compound — famous as a bark-beetle pheromone — that appears in the TGS, urine and breath of adult male Asian elephants in musth. Its concentration increases as bulls mature, and the ratio of its two mirror-image forms shifts through musth.
- **Teenage vs mature bulls:** young Asian bulls in their first musth produce a **sweet, honey-like** secretion; mature bulls produce **malodorous, acrid** secretion. The smell itself advertises the bull's maturity.
- **Who responds:** in bioassays, females in the **follicular phase** (approaching ovulation) were most responsive to frontalin and often followed up with mating-related behaviour. Adult males were mostly indifferent, while younger subadult males often avoided it.
- **Other signals:** the other well-established elephant pheromone, **(Z)-7-dodecenyl acetate**, is released in the urine of Asian females nearing ovulation. African elephants are less studied, and genome-based work on their odorant-binding proteins is only beginning to identify their chemical signals.

06 Do elephants sweat?

Short answer: not in the usual sense. Microscope studies of elephant skin have not found ordinary sweat glands, and elephants also lack the **sebaceous (oil) glands** that keep most mammals' skin supple. That matters, because a large body makes a lot of heat and has relatively little surface area to lose it from — and in Hwange or Kruger, air temperatures can top body temperature.

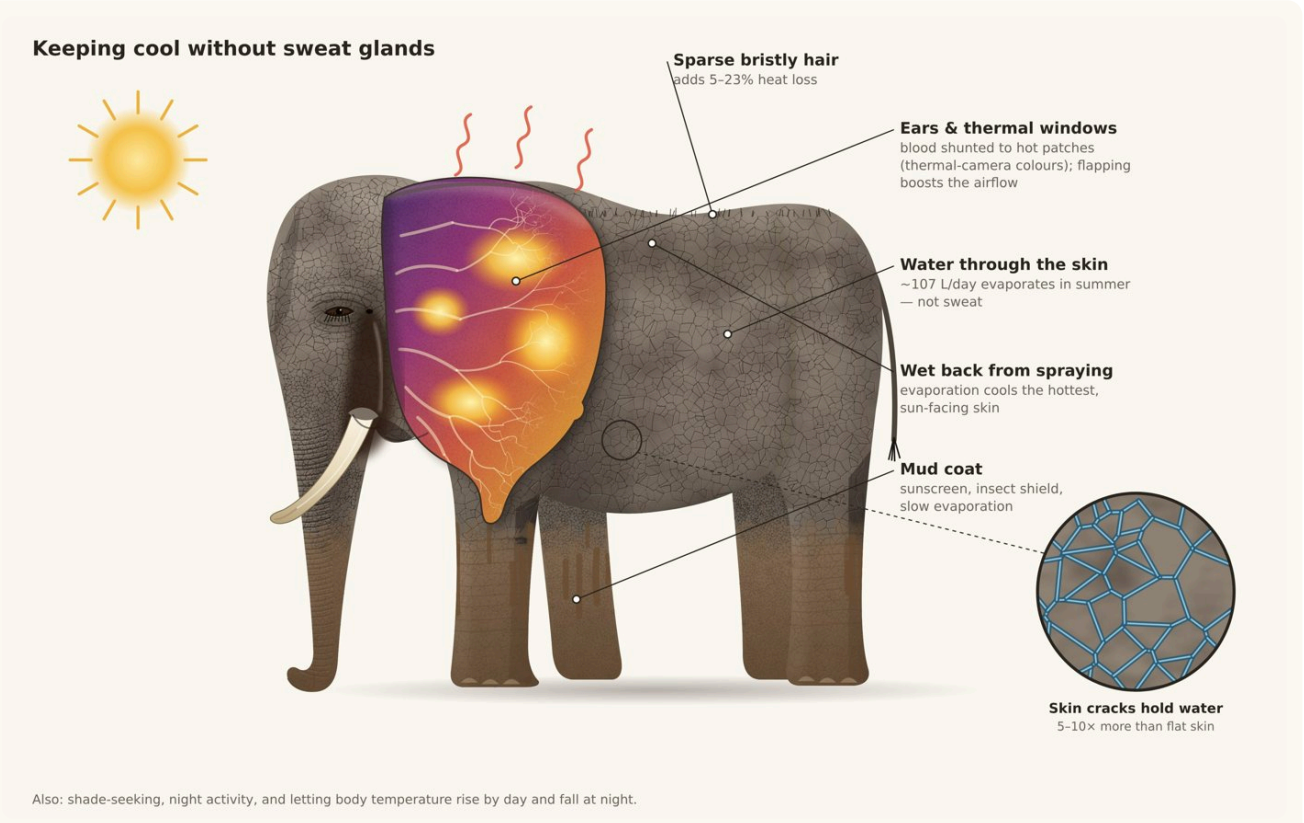


Figure 7. How elephants shed heat without sweating. The ear is shown in thermal-camera colours, with hot patches marking thermal windows.

WATER THROUGH THE SKIN

Elephant skin is unusually permeable. Water diffuses through it and evaporates — called **transepidermal** or **cutaneous evaporative water loss** — at rates high enough to meet thermal needs. Measurements on three African elephants found evaporation from dry skin was about **50% higher in summer than in winter**. Scaled to an elephant's whole surface, that is roughly **107 litres a day in summer and 72 in winter** — around half and a third of daily drinking.

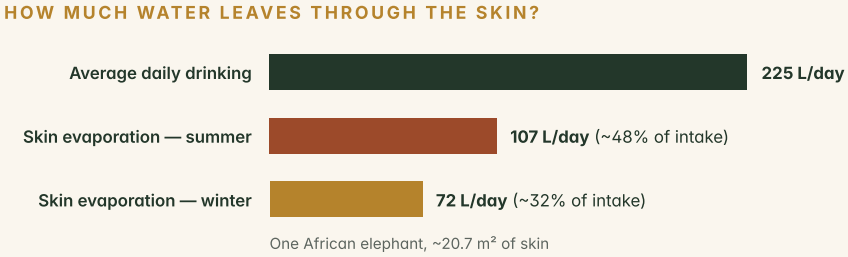


Figure 8. Estimated daily water lost through the skin, compared with average daily intake (Oregon study of African elephants).

CRACKED SKIN AND MUD

The wrinkled surface of an African savanna elephant is a network of genuine **cracks, micrometres wide**, in the outermost skin layer (the stratum corneum, about 50 times thicker than ours). These channels hold **five to ten times more water** than flat skin would and grip mud far better, which also protects against sun and parasites. Newborn calves don't have the cracks yet, and Asian elephants don't have them at all.

EARS AS RADIATORS

The ear is thin, enormous and packed with blood vessels. Blood-flow measurements in African elephants showed heat lost from the ears accounts for a substantial share of the animal's total heat-loss needs, and one analysis concluded that convection and radiation from the ears alone could cover all of it. Elephants control ear blood flow and fan their ears to boost the effect. Thermal-camera work also shows **thermal windows** — sharply defined warm patches on the ears and body where blood is diverted to the surface — appearing more often as temperatures rise and in heavier animals.

HAIR, BEHAVIOUR AND HEAT STORAGE

Elephants' sparse bristly hair improves heat loss by **more than 5%, and by up to 23% in still air**, by stirring the boundary layer of air over the skin. On top of that comes behaviour — shade, drinking, wallowing, spraying, dust-bathing, and being more active in cooler hours — and the ability to let body temperature drift up during the day and dump the stored heat at night.

MYTH CHECK: "ELEPHANTS SWEAT FROM THEIR TOENAILS"

You'll hear this from handlers and some zoo materials, and an old elephant-care treatise does describe a slight oily moisture around the tops of the nails. But published skin histology has not identified sweat glands, and the scientific literature treats elephants as lacking them. **Treat the toenail claim as unverified.** The safer line for guests: elephants don't sweat; the closest thing they have is the temporal gland — itself a modified sweat gland — and its job is communication, not cooling.

07 Field notes for guides

How to read a streaming temple on a game drive:

READ THE COMBINATION

Streak alone ≠ musth

In African elephants, look for TGS *plus* constant urine dribbling (wet inner hind legs, a sour smell), a greenish discoloured penis sheath, and the "musth walk" — head high, chin tucked, ears tense and spread.

USE EVERY SENSE

Listen and smell

Musth bulls give a distinctive low, pulsating "musth rumble" and carry a strong odour you can often smell downwind.

CONTEXT WITH FEMALES

Arousal, not danger

A cow streaming during a noisy family reunion is showing social arousal. Sustained streaming in a separated or harassed female is worth noting as a possible sign of disturbance.

SAFETY

Respect the bull

Musth bulls can be short-tempered and unpredictable toward vehicles and walkers. Give extra distance, never block their path, and avoid placing the vehicle between a musth bull and females he is following.

A GREAT GUEST MOMENT

Point out the gland, explain that it's a modified sweat gland unique to elephants — then pivot to the ears and the mud as their real air-conditioning.

08 Quiz

Fifteen multiple-choice questions. Choose one answer for each — the key with explanations follows.

1 Where is the temporal gland located?

A. Behind the ear
B. Midway between the eye and the ear
C. At the base of the trunk
D. Above the eye

2 What kind of gland is the temporal gland?

A. A modified apocrine sweat gland
B. A salivary gland
C. A tear gland
D. An endocrine gland with no duct

3 In African elephants, temporal gland secretion on its own means…

A. The bull is definitely in musth
B. The elephant is sick
C. Not necessarily musth — females and calves secrete too
D. The elephant is overheating

4 Which hormone rises dramatically during musth?

A. Insulin
B. Testosterone
C. Oxytocin
D. Melatonin

5 What did the Kruger dung-sample study confirm about timing?

A. Signs appear before hormones rise
B. Androgens usually rise before visible musth signs
C. Hormones don't change in musth
D. Musth only happens in the wet season

6 Which stress hormone tends to rise with testosterone in musth bulls?

A. Adrenaline only
B. Thyroxine
C. Cortisol
D. Prolactin

7 Who scientifically described musth in African elephants, and when?

A. Iain Douglas-Hamilton, 1972
B. Joyce Poole and Cynthia Moss, 1981
C. Daphne Sheldrick, 1990
D. It has never been confirmed

8 Around what age did Amboseli bulls first come into musth, on average?

A. 10
B. 18
C. 29
D. 45

9 Which compound in Asian bull TGS acts as a pheromone and increases with maturity?

A. Frontalin
B. Caffeine
C. Histamine
D. Urea

10 Which females responded most strongly to frontalin?

A. Pregnant females
B. Females in the follicular phase (approaching ovulation)
C. Old non-breeding females
D. Females with young calves

11 Do elephants have ordinary sweat glands in their skin?

A. Yes, all over the body
B. Only on the ears
C. No — histology hasn't found them
D. Only in calves

12 Roughly how much water can an African elephant lose through its skin per summer day?

A. About 5 litres
B. About 25 litres
C. About 107 litres
D. About 400 litres

13 The cracks in African elephant skin hold how much more water than flat skin?

A. The same
B. About twice as much
C. Five to ten times more
D. A hundred times more

14 What happened in Pilanesberg when mature bulls were introduced?

A. Young bulls' musth became longer
B. Young bulls' musth became brief and rhino killings stopped
C. Nothing changed
D. The older bulls left the reserve

15 Besides TGS, which sign most reliably indicates an African bull is in musth?

A. Ears flapping on a hot day
B. Continuous urine dribbling
C. Dust-bathing
D. Feeding on bark

09 Answer key

#	ANSWER	WHY
1	**B — Midway between the eye and the ear**	It sits in the temple hollow, roughly halfway between the eye and the ear opening.
2	**A — A modified apocrine sweat gland**	It is a modified apocrine sweat gland, found only in elephants.
3	**C — Not necessarily musth**	African females, juveniles and calves secrete, especially in social excitement.
4	**B — Testosterone**	Musth is driven by a large testosterone surge; captive studies recorded levels often above 100 ng/ml.
5	**B — Androgens usually rise first**	The androgen rise usually comes before visible signs, supporting it as the trigger of musth.
6	**C — Cortisol**	Testosterone and cortisol were positively correlated in bulls that showed musth.

#	ANSWER	WHY
7	**B — Joyce Poole and Cynthia Moss, 1981**	Poole and Moss described it from Amboseli in 1981.
8	**C — 29**	Mean age at first musth was about 29; early episodes are brief.
9	**A — Frontalin**	Frontalin — also a bark-beetle pheromone — becomes more prominent as bulls mature.
10	**B — Follicular-phase females**	Females approaching ovulation were most responsive and often showed mating-related behaviour.
11	**C — No**	Histology hasn't found them. Elephants lack ordinary sweat glands (and sebaceous glands).
12	**C — About 107 litres**	About 107 L/day in summer vs 72 L in winter — roughly half of daily intake in summer.
13	**C — Five to ten times more**	The micrometre-wide channels hold 5–10× more water and grip mud.
14	**B — Musth became brief; killings stopped**	Older musth bulls suppressed musth in the young males.
15	**B — Continuous urine dribbling**	Constant urine dribbling, together with TGS and musth behaviour, defines musth.

SCORING

13–15 expert guide · **9–12** solid · **under 9** re-read Sections 02, 03 and 06.

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Hormone values come from different studies, methods and animals and are shown to illustrate scale. Figures are simplified schematics.

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