Musth in Elephants

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Animal behaviour is intimately connected with chemical signaling, often through glandular secretions. This is very significant and obvious in Asian male elephants during their musth period when their temporal glands secrete a fluid with a characteristic odor. Musth gland activity greatly influences the elephant society as well as man-elephant interaction.

Elephants have had a chequered association with humans. They were used to push or drag heavy items in times of war and during peacetime, were employed in logging operations. Mughal emperors captured and used elephants for hunting, in war and even for executions. The British managed hundreds of elephants for forestry work all over the subcontinent and often for hunting tigers. Artists have left many paintings of elephants kept by the Mughal emperors – one in musth is shown in *Figure* 1. Many more Mughal paintings show musth elephants, though the characteristic extended penis is not depicted in any (perhaps an embarrassment for the artist!). The elephant is loved as a manifestation of the Lord Ganesha and has been used in temple processions and as a part of royal entourage throughout the country. In spite of its long association with man, we have not been able to domesticate elephants fully as we have domesticated other animals like dogs for example. This is arguably due to the 'musth' condition that occurs periodically in males when they become temperamental and very often aggressive. Instances are many when musth elephants have killed their mahouts. The musth period lasts a few months and is characterized by a secretion from the temporal glands that has a significant odor (recognizable even by humans).

Keywords
Musth, androgens, chemical signaling, Asian elephant, testosterone.

As of now, our captive elephants are in hundreds and are very expensive to maintain. They are hired out when possible to

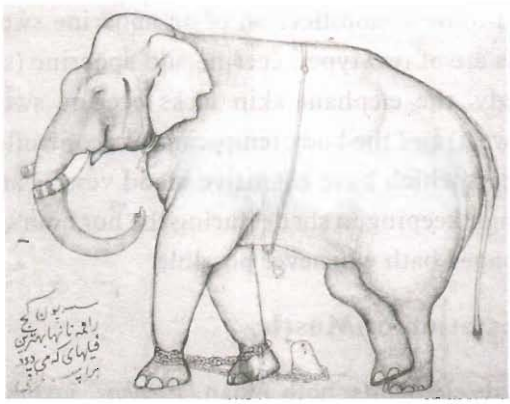


Figure 1 (left). Pawan Gaj, Jehangir's elephant (the emperor's writing with name of the artist Nanha). Courtesy: Marg Publications [1].

Figure 2 (right). Early musth.

recover some of the maintenance cost. The animals with the different Forest Departments are used to carry visitors for viewing wildlife in sanctuaries. They are also used in tourism promotion, since many visitors enjoy a ride on an elephant! Zoos all over the world have Asian elephants. Most people believe they are essential for temple functions. Due to these reasons, and also since they are integrated with the ethos of our country, we have to find ways to manage them suitably, musth or no musth. In places where elephants occur naturally, there is conflict when elephants infringe on areas of human activity. Instances of wild elephants raiding farms at forest boundaries are becoming increasingly common and this gets compounded when males in musth are involved. A deeper understanding of musth gland activity can help us not only to fathom elephant behaviour and evolution but also to find possible ways to control abnormal aggression – perhaps in many other species too!

Figure 3. Tusker with swollen musth gland.

The Musth Gland

Also called the temporal gland, it is located about midway between the eye and ear on either side of the face. The size of the gland may be that of a human fist but this gets enlarged more than double in the active state and the swelling is noticeable (*Figure* 2). When it is not active, the duct end is seen as a hole only. When activity starts in the male, a patch of fluid can be seen. (*Figure* 3). The musth

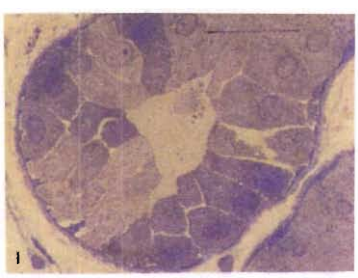
gland is considered to be a modification of an apocrine sweat gland. Sweat glands are of two types, eccrine and apocrine (see *Box* 1). Interestingly, the elephant skin lacks eccrine sweat glands (it doesn't sweat) and the body temperature is controlled by fanning of the ears which have extensive blood vessels and exhalation from lungs, keeping in shade during the hot hours of the day and a prolonged bath whenever possible.

External Manifestation of Musth

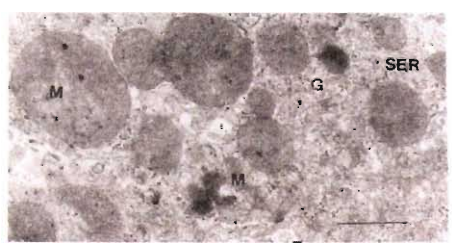
Musth occurs in male elephants, both Asian (*Elephas maximus*) and African (*Loxodonta africana*). In the female Asian elephant,

Box 1. Glands in Skin

The skin is covered mostly by sweat glands. These glands are classified into eccrine and apocrine. Eccrine sweat gland secretion is mostly water, salt and a much less quantity of organic compounds. These glands directly empty on to the surface of skin and are responsible for thermoregulation, i.e. cooling of skin (and body) by the evaporating water taking away the latent heat of evaporation from the surface. The apocrine glands are specialized to produce organic compounds and, where applicable as in scent glands, usually do so after puberty is attained. The apocrine sweat glands occur in the armpit, around the navel and testicular skin. The sebaceous glands of skin are also apocrine emptying their contents (sebum) onto the hair surface maintaining it glossy and are naturally present in large numbers on the scalp. The smell in the armpit is attributed to the bacteria present utilizing the organic glandular exudates rather than the secretion itself and is perhaps characteristic of the individual. The mammary gland is also a modified apocrine gland as are the wax producing glands inside the ear and, of course, the musth gland shown below. *Figure* (A) below shows a low magnification picture in an optical microscope of a thin section of musth gland which is lined with active cells. Discharge into the duct may be noticed. *Figure* (B) is a high magnification picture of part of a cell showing the sub-cellular structure. For a description, please see the section on physiology of musth.



(A) Musth secreting cells and whole duct, Optical micrograph, bar-100μm.



(B) Ultrastructure of secreting cell, Electron micrograph, M- mitochondria, SER – smooth endoplastic reticulum and G – Golgi body, bar- 200 nm

rarely the temporal gland may extrude a secretion when it is pregnant or otherwise stressed. While musth has been well documented for Asian elephants, it was recognized only in the last quarter of the twentieth century in the African species. African elephants, both females and males (mature and subadults) have temporal gland secretion intermittently as an indication of their mental and physiological state but there is pronounced testosterone secretion during musth in only adult males. In the Asian male elephant, both tuskers and tuskless males (mukhnas) come into musth. The temporal gland secretion starts in the subadult stage but becomes typical musth only after reaching maturity. In the adult male, five stages of musth have been described *viz* pre-musth, early musth, mid-musth, post-musth and non-musth, the musth activity being typically over a 16 week period.

Figure 4. Mid-musth with copious secretion.

In pre-musth, only volatile compounds are given out from the temporal gland and may not be noticed by humans. In early musth, the secretion begins as shown in *Figure* 2. Continuous secretion is seen in mid-musth (*Figure* 4) and is characterized not only by the oily secretion and pungent smell, but also frequent urine-dribbling from an extended penis and marked aggression. There is a tendency to spread musth fluid on objects like tree trunks leaving it as a message of the animal's condition (*Figure* 5). The body temperature is higher than normal. The elephant shows decreased appetite and thirst as compared to a non-musth tusker. Activity decreases in late musth when secretion and aggression tapers off into the non-musth condition. At the end of musth, the elephant might have lost almost a tenth of its body weight.

Figure 5. Musth scent marking.

In the African elephant, during musth (correlated with increased testosterone in temporal gland secretion and blood), as many as eight distinct behaviour patterns have been described some of which are common to those of the Asian species mentioned above. Males in musth of both species, show marked aggressive behaviour, like pulling at chains (in the case of captive ones) or lunging at other males that take care to stay out

of reach. Males in musth are also drawn to females (see *Box* 2 on chemical signaling). The animal feels irritated by the discharge and naturalists have noticed that it tries to increase musth flow by pressing the tusk root against a hard surface (*Figure* 5), possibly for scent marking as well. In captive elephants, the animal is seen to manipulate small twigs with the trunk poking the musth orifice with it. Bits of twigs are thus found stuck in the orifice causing further irritation.

The only other mammal that shows a distinct musth period is the male adult camel in rut when it becomes aggressive and also produces a glandular secretion but the condition is not so well pronounced as in elephants.

Since elephants have exceptional olfactory perception (as good or better than a bloodhound), they can smell the musth components even when the condition is just starting in one male

Box 2. Chemicals Implicated in Elephant Behaviour

Most of the work on chemical communication in elephants has been by LEL Rasmussen and her co-workers [2]. In fact, their work 'dominates' the field. They have identified the chemical frontalin as a sex pheromone present in temporal gland secretion during musth. A mature female elephant in its follicular state just before ovulation responds appropriately to the musth male due to the frontalin in the musth secretion. The androgens in musth (metabolised from cholesterol) i.e. testosterone as also dihydrotestosterone derived from it, in serum increases aggression in all rutting mammals, even the 'gentle' spotted deer (*Axis axis*) and the musth elephant is no exception. These are significantly high in mid-musth. The androgens in the urine voided and musth secretion that is liberally smeared everywhere is possibly a marker indicating a signal to the receiver elephant as to the rutting condition (aggression level) of the giver, ie. the musth elephant. Estradiol is also derived from cholesterol and in the brain it is involved in increasing sexual desire. Some of the volatile chemicals present during pre-musth are acetone, isoprene, butanal, 2-butanone, 2-methyl-3-buten-2-ol, to name a few important ones. These may possibly be the chemicals that prevent receiver males from coming into musth. Cyclohexanone is found in early musth. Rasmussen and coworkers have also identified the compound (Z)-7-dodecen-1-yl acetate in the urine of female elephants which increases in concentration during the follicular phase to a peak just before ovulation, as a sex pheromone that elicits erections and pre-mating behaviour from male Asian elephants. These female elephants advertise their condition through urine and tail slappings and wavings and the musth males that are sufficiently aggressive get their mating opportunity to the misfortune of non-musth males who have to bide their time.

during pre-musth and this may inhibit the initiation of musth in the receiver males. This phenomenon has been noted among the camp elephants of the Tamil Nadu Forest Department where records show that only one adult male is in musth at a time. This is perhaps nature's way of preventing conflicts within a group. A musth elephant is also smelt from far away by conspecifics and may be attracted by receptive females who also advertise their condition. (Please see *Box* 2.) Other non-musth males take care to avoid the musth male, and if there happens to be another male in musth in the area, a conflict can arise.

Chemical Composition of Musth

Hundreds of organic substances have been identified at various stages of the musth condition using GC-MS (Gas chromatography coupled with Mass Spectrometry), HPLC (High Pressure Liquid Chromatography) and other techniques. The most significant compound is testosterone and its derivative dihydrotestosterone – not surprising since the animal is aggressive in most cases and is kept in chains if captive. The temporal gland secretions continue for various periods for around 90 days. Apart from testosterone and dihydrotestosterone, the other predominant compounds are several ketones, proteins, mucopolysaccharides, lipid metabolites, etc., whose relative concentrations vary with the time course of musth. Another significant compound is frontalin, a pheromone described first in insects that is used by the female insect to attract males (*Box* 2).

Many of these compounds are present not only in the musth secretion, but also in the blood serum and urine as well. The urine dribbling has significance in this connection since other elephants smelling it will know the condition of the musth elephant – males avoid it while females in receptive condition may be attracted. Other components like proteins present may fix the lighter components for a higher time period. A few experiments have been carried out to find whether some of the volatile chemicals like cyclohexanone can be used to keep away marauding elephants from crops but this was not a great success

since elephants are perhaps too intelligent to be tricked repeatedly! The response of the opposite sex also to a particular chemical may be different. Pure frontalin evokes no response in males while females in the right stage of ovulation are responsive and get attracted to the male in musth. Males in musth are attracted to females whose urine contains the female pheromone Z-7 dodecenyl acetate. The whole gamut of chemicals may together transmit an 'honest' message to the receiver on the state of the giver.

Musth and Elephant Behaviour

The most important aspect of musth is the behaviour associated with it. Musth has been conserved through evolution in spite of the loss in body condition suffered during the period. Elephants in musth are very aggressive and dominate other males, which may be stronger physically but not in musth. This is reflected in the testosterone levels in the musth fluid, serum and urine. Possibly, as a result of their aggressive behaviour, musth males are able to get more mating opportunities with receptive females and their genes get transmitted through generations. So, in spite of its negative effects, the musth characteristic has continued in elephant society. It is not that all elephants are aggressive in musth; many as they reach the latter years of fifty or thereabouts, though quite reproductively active, are less aggressive and are safely handled, as observed in captive Asian animals. The elephant from which I got a biopsy of the musth gland when in the active condition was 50 years old but was not aggressive (at least towards his mahout and the elephant doctor) but when he was half the age, he had killed his mahout in an aggressive bout of musth.

Comparatively more research has been done on musth and elephant behaviour in free living African elephants than on the Asian species – not only with regard to chemical constituents in musth but also particularly with respect to vocalizations. Elephants communicate with one another using low frequency sound (infrasound; less than around 20 Hz frequency, the limit

for human hearing). The human ear can, in favourable atmospheric conditions, perceive these elephant vocalizations as a low frequency rumble. Using special equipment, several such calls have been distinguished in the African species including one where musth males produce a characteristic call termed the 'musth rumble'. The consequences of this sound have been analysed by Joyce Poole [3]. Female elephants, which are in oestrus, respond by giving an 'oestrus rumble' and move towards the musth male's call; females not in oestrus show active response while musth males respond aggressively. Non-musth males react by moving away.

There has also been a lot of debate as to what extent the signals given, i.e.. chemical constituents and musth rumble, are really 'honest' (and not 'faked') in order to get mating opportunities and how this has evolved vis a vis signaling mechanisms in other species. The more complex these signals are, the more honest they can be for other elephants to respond suitably. However, there will be a cost to the giver in that his metabolism would have to be more rapid to give rise to these signals (see below). The consequence is that the body condition of the musth male deteriorates fast and thus he can be in musth only when in peak physical health. At such times, he may even be able to guard a few oestrus females and have exclusive access to them. In African elephants, it has been shown that both healthy condition and musth secretion are required for mating success. Fights between males do occur if both these factors are balanced only to about the same level and receptive females are not readily available. Since fights can also result in harmful if not fatal injuries, it may also be advantageous for one contestant to seek mating opportunity elsewhere or seek unguarded receptive females or bide his time. How the various factors vary with age has also been worked out.

In the wild, the females form a group that is led by an old female or matriarch and others are related to her to a greater or lesser degree. The males on reaching puberty separate from the herd and seek females from other groups (which prevents in-breed-

ing) for mating. The wandering males may form a small group with a dominant male and his 'chelas'. The chelas don't come into musth when the dominant male comes into the condition. It has also been shown that the musth secretion, serum or urine of sub-adult males does not contain testosterone and so there is no aggression.

When conflicts arise between two musth elephants and one is driven away, the defeated male may turn into a 'rogue' elephant venting his fury on others, especially man, in a case of redirected aggression.

Physiology of Musth

The chemicals found in musth and other body fluids have to be produced by body metabolism. Starvation noticed during musth can itself change the metabolism and many of the compounds secreted may reflect this effect. This is possibly the cause for increase in ketones in the breath, urine and musth secretion. The source for testosterone in males and estrogen in females is cholesterol (produced by lipid metabolism). Hormones initiate the changes in the sexes leading to sperm production in males and ovulation in females at the appropriate time. The testosterone levels in the temporal gland secretion during musth reaches 0.5 mg/mL and in the serum it is about one tenth of this. Other degradation products connected with lipid metabolism are also generated. For the production of high quantity of androgens, the cellular activity gets increased manifold. In a typical musth gland cell, the organelles connected with lipid metabolism like smooth endoplasmic reticulum, golgi bodies and mitochondria exhibit hypertrophy and ultimately, the cells rupture exiting the numerous cellular components in the musth fluid. In the secreting cells of the temporal gland, the mitochondria involved with energy exchange are numerous and have tubular cristae increasing the surface area for the many reactions to take place and are closely associated with lipids. Of all androgen secreting cells, the temporal gland ones producing musth, seem to have the highest density of mitochondriae with the highest density of cristae.

The androgen testosterone is also considered as a prohormone since dihydrotestosterone, a more potent androgen, is derived from it as also estradiol (*Box* 2) which in the brain, increases sexual desire, a noticeable condition in musth.

Is Musth Controllable?

Musth in elephants is a normal process. It becomes a problem only in the case of man-elephant interactions. Guidelines have been issued in Kerala (where many temples own tuskers for temple rituals), on care of elephants in musth to avoid harm to humans. The mahouts know that animals in musth misbehave but laxity on their part can lead to tragedy. Very often the animal becomes quite docile subsequent to the aberrant behaviour almost as if it regrets its misconduct and the mahouts consider this normal and a factor not to be held against the elephant! A drug, Leuprolide acetate has been tried to suppress the condition in captive elephants by reducing testosterone production. The same drug is injected to treat prostate cancer in humans where also it acts by reducing testosterone in circulation (one may end up with slightly female characteristics as the general androgen balance is upset). Obviously, long-term use of the drug can change behaviour in elephants (and humans!)

More studies are called for in all aspects of musth; the ultrastructural pathology, the signals involved in transforming dormant cells to musth secreting cells, detailed physiology as also the behavioral responses and of course possible ways to control the aggression to the extent of preventing fatalities but not normal sexual behaviour.

Acknowledgements

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Suggested Reading

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