Journal of Experimental and Basic Medical Sciences 2021;2(2):139-146

Review

Rat Sexual Behaviours

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Rats have been used in medicine for research for a long time. They continue to offer a wide variety of interesting and diverse models relevant to the human body and mechanisms. Cancer, toxicology, and diabetes are only a few examples. There are several reasons why rats are the most used animals compared to the other animals. One of the reasons is rats' physiology. Rats and humans are similar compared to their physiology. Rats reflect appropriate models for cardiovascular disease. Secondly, in the studies of physiology such as learning and memory, rat's models are very useful for modeling human's physiological systems because rats are more intelligent compared to other animals used in laboratories. For example, mouse. Finally, human's sexual and social behaviour paradigms can be understood better with the social and sexual behaviours in rats. Rats could be perceived as mirrors of human sexual and social conduct. As a result, their behavior, especially sexual behavior, is critical in understanding human behavior.[1-4] In this paper, Sexual cycle of rats, female and male rats' sexual behaviours, used laboratory models to study sexual behaviours in rats, factors that affect sexual behaviours in rats and comparison of rats' and humans' sexual behaviours are discussed.

ABSTRACT

Sexual behavior in rats has been a fascinating topic for many research because rats are as cosmopolitan as humans and their social and sexual activities can reflect human behavior. Female rats display lordosis and paracopulatory behaviors, while male rats engage in sexual behaviors such as mounting, intromissions, and ejaculations. Many models, such as the bilevel chamber, runway test, and others, are used to investigate similar behaviors in rats. Experiments in these models focused into the factors that influence rat sexual behavior. Dopamine, serotonin, prolactin, oxytocin, and androgen are only a few of the chemical and biological structures that influence various aspects of sexual behavior in rats. These findings are proved by many researches. This review focuses on sexual behavior in general.

Keywords: Dopamine, ejaculation, lordosis, rats, sexual behaviour, sexual motivation.

SEXUAL CYCLE IN RATS

The sexual cycle in rats is divided into three stages: the precopulatory phase, copulatory phase, and executive phase. Sexual contact prepares sex partners for the copulatory process in the precopulatory phase. Anogenital and body sniffing, as well as circling around the female rat, are signs of sexual contact. Female rats start the copulatory phase with paracopulatory behaviours to attract the male rat's interest. In this phase, male and female rats have their own language of sex. They show different behaviours. For example, while male rats show mounts, intromissions and ejaculations, female rats show lordosis behaviours. These terms will be explained later for better understanding of sexual behaviour in rats. After the ejaculation, the executive phase occurs. In this phase, male rats recover their energy for additional sexual attempts instead of remaining their sexual activity. This interval is named as a postejaculatory interval. When this interval ends, a new sexual cycle begins with mounts of male rats.[5,6]

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Cite this article as: Karabaşoğlu C, Erbaş O. Rat Sexual Behaviours. JEB Med Sci 2021;2(2):139-146.

doi: 10.5606/jebms.2021.75650

Received : June 04, 2021
Accepted : June 30, 2021
Published online : September 29, 2021

SEXUAL BEHAVIOURS IN FEMALE RATS

a. General properties of sexual behaviour

The sexual activity of female rats can be applied to paracopulatory and lordosis behaviors as well. Paracopulatory behavior is a form of behavior used to attract the interest of male rats. Ear wiggling, hopping, and darting are examples of these activities. Darting is a behavior in which she reveals her body to attract the attention of male rats with runaways. Hopping is jumping with four legs in a short period of time. These behaviours are dependent on hormones. These hormones are produced in the ovary. Paracopulatory behaviours lead to initiation of copulation, and they regulate the patterns of sexual behaviours. Another significant component of sexual behaviour in female rats is lordosis behaviour. Lordosis is known as a reflex, and this reflex occurs with the presence of hormones such as estrogen. Generally, lordosis happens when male rats exhibit mounts and sexual stimulations. Also, lordosis is affected by sexual motivation.[2,6]

b. Motivational aspect of sexual behaviour

Female rats' sexual behaviors are divided into two phases: consummatory and appetitive. Copulatory behaviors are part of the consummatory process. Sexual motivation is part of the appetitive process.[7] Sexual motivation is related to paracopulatory behaviors. Male rats' sexual motivation is increased by paracopulatory behaviors. Many studies have backed up this assertion. Furthermore, if female rats continue their paracopulatory behavior for a longer period of time, their sexual motivation would grow. Finally, the amount of paracopulatory behaviors has a significant impact on sexual desire. Lordosis is another component which is associated with sexual motivation. From the results of many researches, lordosis is observed as indication of sexual motivation.[2,6]

c. Their sexual interaction's importance in social life

During copulation, female rats engage in social activities such as sniffing and looking for the anogenital zone. These actions are unrelated to paracopulatory and lordosis actions. Furthermore, in female rats, social activities are not involved in the control of sexual activity. Many studies have shown that normal behaviors that are not sexual are regulated differently than sexual activities. Many studies proved that normal activities independent of sexual activities are controlled differently than male.[2]

SEXUAL BEHAVIOURS IN MALE RATS

a. General properties of sexual behaviour

Mounts, intromissions, and ejaculations are all examples of male rat sexual behavior. Mount is a paracopulatory reaction in which the penis is inserted into the vaginal canal of a female rat. The male rat then continues to raise its thrust, driving the female rat deeper. After dismounting the female rat, the male rat makes a movement with his forepaws raised.[6,8] Rats are multiple ejaculators. Because of that reason, rats represent many mounts and ejaculations after their first ejaculation.[2] Postejaculatory interval follows the ejaculation. Postejaculatory interval is a process which lasts between ejaculation and new sexual attempt with mount. It lasts approximately 4 - 7 minutes.[2] In some studies, the time between first mount and ejaculation is named as copulatory bout in male rats.[2] To understand male rats' sexual behaviours better, behaviors in copulatory bouts are also essential to comprehend. To achieve ejaculation, male rats require intromissions. In addition, with a variety of intromissions, the penile is stimulated. According to studies, two intromissions are needed to impregnate female rats, and two or more intromissions are required to impregnate the female rats. Therefore, it can be said that numbers of intromissions are critical for male rats. To conclude, Intromissions are very important parts of sexual behaviors in rats because they cause male rats to reach ejaculation and impregnate rats.[6] Another important behaviour is mount. Mount is the initial stage of the consummatory behaviour which includes copulation phases. Mounts are not necessary for ejaculation. When male rats are prevented from displaying intromissions, they show mounts. While mounts are not needed for male rats to achieve ejaculation, they have an impact on copulatory behavior. They play a critical role in copulation's temporal and central patterns.[6] Postejaculatory interval is also the component which plays a major role in sexual behaviour. But, this component is poorly understood.[2,6] Finally, ejaculation latency is the time between first intromission and ejaculation. If the ejaculation latency decreases, it indicates that male rats have more intromissions and are more active.[6]

b. Motivational aspect of sexual behaviour

Male rats have a variety of sexual habits. One of them is motivated by sexual desire. Many different forms of sexual behaviors are linked to sexual motivation. Sexual motivation is associated with anticipatory behavior. Anticipatory behavior can be defined as a male rat looking for a female rat to have a sex. Also, sexual motivation is associated with the initiation phase, which is when copulation begins. While sexual motivation causes the copulation, increased levels of anxiety prevent the copulation.[9] Also, sexual motivation affects the copulatory rate which is defined as "the ability to satisfy the sexual drive and depends on sexual experience." Bialy et al.[9] Increased numbers of mounts are related to sexual motivation[6] In conclusion, Sexual motivation plays an important role in sexual behaviours in male rats.

c. Their sexual interaction's importance in social life

Rats' social interactions were an attractive subject for many researchers. Rats' almost social interactions happen during the copulation. They spend their time without social interactions except for sexual activity. Wandering and resting are the most male rats' do in their normal life. In the copulation, sociosexual interactions are known as sniffing and watching the female rat.[2]

EXPERIMENTAL MODELS OF SEXUAL BEHAVIORS IN RATS

Several models are designed to study sexual behaviours in rats. Each male and female rats have their own set of templates. These models are divided into many sections that look into various aspects of rat sexual conduct. There are several models available. Examples of these models are bilevel chamber, runway test, standard copulation cage, incentive motivation testing arena and semi natural environment are examined briefly in this paper.

a. Bilevel chamber

This model is used to study the behavior of rats during copulation and sexual motivation. Bilevel chambers, for example, are used to study female rats' appetitive and consummatory behaviors.[2,6,10]

b. Runway test

This test is excellent for determining a man's sexual motivation. This design uses a protocol based on male sexual behavior as an example of one procedure. In the stimulus, a female rat is present, while a male rat is present in the startbox. The experiment begins with the runway doors being opened. The male rat's speed is measured using photocell detectors. The male rat's goal in the stimulus is to reach the female rat. Male rats, according to the findings, move faster when they ejaculate.[6]

c. Standard copulation cage

The majority of the time, this model is used to research sexual behavior in rats. In most cases, the cage contains one male and one female rodent. In addition, these species are more likely to have a history of sexual behavior. This produces more precise results. Rat copulation is predicted as a result of the experiment conducted in this model. Many research focused their experiment on copulation behaviours in rats with this model.[2]

d. Incentive motivation testing arena

The aim of this model is to research rats' sexual motivation. The amount of time spent in the reward zone during the evaluation is a significant factor. Sexual motivation is analyzed and measured using various aspects in this model.[2,6]

e. Semi natural environment

This model is designed to study rats' sexual and social experiences. Female rats have the ability to hide from male rats, which increases observation outcomes. The estrus behavior of female rats, which is triggered during sexual activity, can also be studied.[2,11]

FACTORS AFFECTING SEXUAL BEHAVIOURS IN RATS

a. Dopamine

Dopamine is a neurotransmitter that plays many key roles in the brain and nervous system. Generally, dopamine is involved in motivational and rewarding behaviours. Because of it's neuromodulatory function, Dopamine interacts with many neurotransmitters, including monoamine neurotransmitters. It's stimulated by monoamine neurotransmitters. When dopamine is released to synapse, dopamine binds to the dopamine receptors such as D1, D2, D3, D4 and D5. These receptors function as G - protein - coupled receptors, which play a key role in activation of cellular responses. Sexual activity is associated with motivational and reward behaviours. Dopamine affects the rewarding nature of sexual

behaviour.[14] Especially, dopamine is associated with desire.[13] Therefore, the idea that dopamine can play an important role in sexual behaviour is widely accepted. From this idea, many researches centered on the relationship between sexual behaviour and dopamine. Dopamine can be seen as a candidate to be the most focused and studied neurotransmitter in this field. Dopamine receptors have a big role in sexual behaviours in male rats.[12] Dopamine affects the motivational aspect of sexual behaviour. In both male and female rats, increase in levels of dopamine is related to sexual motivation. Also, dopamine's levels are elevated during the copulation. Apomorphine is a dopamine antagonist and is used to test the role of dopamine on male rats' sexual behaviour. Although low doses of apomorphine reduced the number of ejuculations, high doses of apomorphine increased the number of ejaculations and mounts.[16] Dopamine, and it's agonists such as amphetamine and amfonelic acid have a powerful impact on rats' sexual and locomotor activity. They increased the locomotor activity. In addition to this, haloperidol and cis(Z)-flupentixol known as the dopamine receptor antagonists are observed to minimize sexual behavior.[17] Dopamine rises during the copulation.[15] From this observation, the change of dopamine levels in nucleus accumbens during sexual behaviour is investigated by using in vivo microdialysis in one research. The increase of dopamine in the extracellular only occurs ıf female rat is rewarded.[18] In addition, dopamine transmission increases during the copulation.[19] Dopaminergic system is associated with regulation of expression of penile erection. Penile erection is a complex sexual reflex. It requires many conditions and interaction. To examine the role of dopamine on penile erection, apomorphine is injected into male rats' the paraventricular nucleus (PVN) region, which is found in hypothalamus. In this experiment, when doses of apomorphine are injected into PVN, penile erection occurs without the intervention of female rats. This finding gives us that dopamine plays a major role in erection of penile. Also, the entry of oxytocin into the process of penile erection has been discovered. Dopamine also interacts with other hormones such as oxytocin, which have a neuromodulatory role in sexual behaviour. Oxytocin neurons express the dopamine receptors, and this interaction could indicate that a dopamine - oxytocin connection exists. Dopamine affects the lordosis behaviour and dopamine has been discovered to be involved in the anticipatory phase of sexual behaviour.[20,21]

b. Serotonin

Serotonin (5-HT) is a neurotransmitter that plays an important role in regulating various psychological processes and behaviours such as regulating mood, reward and learning. Serotonin is released as the lateral hypothalamus. Serotonergic system affects sexual behaviour and this system is related to a number of sexual disorders. Serotonin and serotonin receptors (5-HT Receptor) belong to the serotonergic system. Sexual behaviour in rats is organized by brain areas. Serotonin and its receptors have a significant role in these neurochemical pathways.[22,25,27] Therefore, the effects of serotonin and its receptors on sexual behaviour in rats is thought to exist. Generally, while an increase of 5-HT inhibits sexual behaviours, a decrease of 5-HT leads to facilitating the sexual behaviours. For example, lordosis behaviour is inhibited by enhanced serotonergic activity and also 5-HT1A plays an inhibitory role and 5-HT2 plays a facilitator role in female rats' sexual behaviours.[22] In male rats, 5-HT1A plays a facilitator role and affects various aspects of sexual behaviour.[23,24] Also, effects of Selective serotonin reuptake inhibitor (SSRI) on sexual behaviours in male rats is examined. Researchers discovered no inhibitory effects on male rat sexual activity in one sample. Another study found that SSRIs and other serotonin inhibitors lengthen the time between ejaculations and reduce the number of ejaculations. Furthermore, serotonin transporters (SERT), which transport serotonin through neurons, have no effect on female rats' sexual conduct.[25-27] Serotonin receptors affect female sexual behaviours directly such as lordosis. Some of 5-HT antagonists cause lordosis behaviour's activity to decrease, while some of them cause increasing. In addition, 5-HT modulates sexual behaviours in female rats.[28] 5-HT receptors stimulate and inhibit certain phases in the sexual cycle. For example 5-HT1A receptors play an inhibitory role in the copulatory phase.[27] In conclusion, serotonin, and its receptors have effects on sexual behaviours in male and female rats.

c. Prolactin

Prolactin is the pituitary hormone that is responsible for the production of milk in mammals and humans and also prolactin is encoded by the PRL gene.[29,30] Prolactin plays an important role in sexual function. Prolactin is involved in modulation of serotonergic and dopaminergic systems. These systems have an impact on sexual function.[31] As a result, prolactin is thought to play a part in sexual behaviour. Prolactin is secreted during the orgasm.

After the orgasm, prolactin affects the reproductive organs and sends a signal to systems which control sexual function.[32] Prolactin also affects prostate organization, and it is found that prolactin receptors are located in the prostate.[33] Prolactin is the one of the peptide hormones that affects the prostate's function directly. Also, prolactin is also secreted in order to respond to ejaculating.[33] Therefore, the connection between sexual behaviour and prolactin whether it exists or not is investigated in a good deal of research. Prolactin has been shown to inhibit and influence sexual activity in several studies.[34] Hernandez et al.[33] performed research that examines the effects of prolactin on sexual behaviour in male rats. According to their results, prolactin is released in the process of ejaculation. High levels of prolactin are released in second ejaculations. From the third ejaculation, the released level of prolactin begins to decrease. However, some increased levels of prolactin that do not affect the sexual behaviour of male rats is also indicated. The rise in levels is correlated to changes in the prostate epithelium. Prostate cancer is caused by these changes.[33] In other research, release of prolactin in sexual activity in mice has been demonstrated, as well as the relationship between prolactin and the post-ejaculatory refractory period. For men, the post-ejaculatory refractory phase is the interval between orgasm and the next erection. According to the findings, prolactin has no impact on the post-ejaculatory refractory era.[35]

d. Oxytocin

Oxytocin (OXT) is a neuropeptide and peptide hormone that is encoded by the OXT gene and plays a role in social bonding, learning and milk production. OXT is often referred to as the "love hormone." It is generated in hypothalamus, and its synthesis is regulated by gonadal steroids by gonadal steroids such as progesterone and testosterone.[36-40] OXT is a neurotransmitter that plays a role in central nervous system processes as well as sexual activities in rats, such as stimulating reproductive organs.[37] For example, stimulation of vaginocervical is correlated with release of OXT.[37] In male rats, release of oxytocin causes penile erection and affects female's sexual activity and interest negatively.[38] It affects consummate behaviour and motivational aspects of sexual behaviour in rats.[41] In other research, oxytocin is injected into male Wistar rats to examine the role of oxytocin in sexual function. According to the findings, the number of intromissions is decreased after oxytocin is injected.[42] Also, OXT is linked to mechanisms which have an effective role in the post-ejaculatory refractory period and oxytocin has been shown to reduce the time of post-ejaculatory refractory period by some research.[43,44] In other research, it is shown that reduced levels of oxytocin lead to decreased sexual motivation in male rats. Oxytocin is obviously involved in sexual behavior in rats.[41]

e. Androgen

Androgen is a steroid hormone produced by males. One example of androgen is testosterone and the function of testosterone is known as the development of male reproductive systems. Androgens have an effect on the immune, nervous, and sexual systems, as well as sexual appetite and motivation.[45] In males, testosterone is secreted in testis. When testosterone arrives in the brain, it binds estrogen with the aromatase. Aromatase is an enzyme which is responsible for converting testosterone into estrogen. Estrogen binds estrogen receptors. Thus, initiation of sexual activity occurs in males. In addition to this, the association of estrogen receptors with testosterone has a significant effect on sexual behavior. Estrogen is secreted in the ovary of female rats and attaches to alpha-fetoprotein, resulting in the initiation of sexual activity in female brains. Also, the regulation of sexual behaviours in rats is made by the hypothalamic-pituitary-gonadal axis (HPG axis). The LH hormone, which regulates testosterone, is stimulated by this hypothalamic region. As a result, androgen's influence on sexual behavior seems to be inevitable. Many studies in rats looked into the relationship between androgen and sexual behavior.[46] Diane M. and her colleagues investigated the function of progesterone in male rats' sexual behavior. Their findings revealed a correlation between progesterone and the neurochemical metabolisms of male copulatory conduct.[47] Sexual reflexes like erection are essential components of sexual behaviour. Androgen is necessary for sexual reflexes. The release of androgen triggers these reflexes.[48] Testosterone belongs to the class of androgens, and its actions are investigated by many researchers. Androgens use the androgen receptor (AR) to carry out their functions. AR is a member of the steroid hormone nuclear receptor family. It plays a vital role in many systems of the human body, including the immune system and reproductive systems.[49] The interactions of testosterone and androgen receptors were

investigated in one study to learn more about the effect of testosterone on sexual behavior in male rats. Testosterone's role on sexual behaviour of male rats is very critical and Stimulation of AR by Testosterone is required for activation of male sexual activity are learned by this experiment. This experiment supported the interaction of AR and testosterone plays a critical role in sexual behaviour in male rats.[50] In other research, effects of testosterone on sexual behaviours in male rats are not detected.[51] Another member of androgen is progesterone. Progesterone affects sexual behaviours pathways in male rats, and this finding can be applied to mammals. To understand the role of progesterone on sexual activity in male rats, some capsules are implanted into the male rats. Some of these rats have progesterone-only capsules, others have testosterone-only capsules, and still others have both progesterone and testosterone capsules. According to the results of this experiment, effects of progesterone on sexual behaviour in male rats appear to be evident.[47] In conclusion, androgen plays a key role in sexual behaviours of rats.[22]

CAN RAT SEXUAL BEHAVIOR BE USED AS A MODEL FOR HUMANS?

The sexual behaviors of rats have long been studied. Many experiments and observations have shown that human and rat sexual activities are identical. Also, several studies have shown that sexual dysfunctions in rats can be used to model human sexual dysfunctions. For example, delayed ejaculation latencies in rats can be used for modeling ejaculatory dysfunctions in humans.[52] Furthermore, one research supports the vaginal and genital responses in rats may reflect the humans' sexual responses.[8] Finally, the act of ejaculation differs between male humans and male rat during sexual intercourses. In human male, while sexual activity ends generally with ejaculation, male rats' sexual activity does not end with ejaculation because rats are multiple ejaculators.[2] To sum it up, Although there are some variations between humans and rats in terms of sexual activity, rats' sexual behavior can be used to model human sexual behavior.

Conclusion

Many studies have shown the relevance of sexual behaviors in rats. Numerous studies have demonstrated that sexual and social behaviors in rats may reflect human dysfunctions and behaviors. To gain a deeper understanding of rats' sexual behaviors, their sexual behaviours should be examined from a variety of perspectives such as sexual motivation and sociosexual factors more. The number of behavioural paradigms should be increased to explore more facets of sexual behaviours. These designs can be remodelled better for different purposes. Finally, factors do not affect sexual behaviours from only one aspect. Researchers should concentrate on the impact of these factors on various aspects of sexual behavior in rats, as well as interactions between these factors, such as oxytocin and dopamine.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Iannaccone PM, Jacob HJ. Rats! Dis Model Mech 2009;2:206-10.
2. Chu X, Ågmo A. Sociosexual interactions in rats: Are they relevant for understanding human sexual behavior? Int J Psychol Res 2016;9(Special Issue):76-95.
3. Modlinska K, Pisula W. The Norway rat, from an obnoxious pest to a laboratory pet. Elife 2020;9:e50651.
4. Sengupta P. The laboratory rat: Relating its age with human's. Int J Prev Med 2013;4:624-30.
5. Hlinák Z. Precopulatory behaviour in male rats: Ethological analysis and functional considerations. Act Nerv Super (Praha) 1990;32:12-34.
6. Heijkoop R, Huijgens PT, Snoeren EMS. Assessment of sexual behavior in rats: The potentials and pitfalls. Behav Brain Res 2018;352:70-80.
7. Cummings JA, Becker JB. Quantitative assessment of female sexual motivation in the rat: Hormonal control of motivation. J Neurosci Methods 2012;204:227-33.
8. Olivier B, Chan JS, Pattij T, de Jong TR, Oosting RS, Veening JG, et al. Psychopharmacology of male rat sexual behavior: Modeling human sexual dysfunctions? Int J Impot Res 2006;18 Suppl 1:S14-23.
9. Bialy M, Bogacki-Rychlik W, Przybylski J, Zera T. The sexual motivation of male rats as a tool in animal models of human health disorders. Front Behav Neurosci 2019;13:257.
10. Pfaus JG, Smith WJ, Coopersmith CB. Appetitive and consummatory sexual behaviors of female rats in bilevel chambers. I. A correlational and factor analysis and the effects of ovarian hormones. Horm Behav 1999;35:224-40.

11. Reith S, Hoy S. Review: Behavioral signs of estrus and the potential of fully automated systems for detection of estrus in dairy cattle. Animal 2018;12:398-407.
12. Melis MR, Argiolas A. Dopamine and sexual behavior. Neurosci Biobehav Rev 1995;19:19-38.
13. Berridge KC. The debate over dopamine's role in reward: The case for incentive salience. Psychopharmacology (Berl) 2007;191:391-431.
14. Becker JB. Sexual differentiation of motivation: A novel mechanism? Horm Behav 2009;55:646-54.
15. Pleim ET, Matochik JA, Barfield RJ, Auerbach SB. Correlation of dopamine release in the nucleus accumbens with masculine sexual behavior in rats. Brain Res 1990;524:160-3.
16. Hull EM, Bitran D, Pehek EA, Warner RK, Band LC, Holmes GM. Dopaminergic control of male sex behavior in rats: Effects of an intracerebrally-infused agonist. Brain Res 1986;370:73-81.
17. Agmo A, Fernández H. Dopamine and sexual behavior in the male rat: A reevaluation. J Neural Transm 1989;77:21-37.
18. Jenkins WJ, Becker JB. Dynamic increases in dopamine during paced copulation in the female rat. Eur J Neurosci 2003;18:1997-2001.
19. Pfaus JG, Damsma G, Nomikos GG, Wenkstern DG, Blaha CD, Phillips AG, et al. Sexual behavior enhances central dopamine transmission in the male rat. Brain Res 1990;530:345-8.
20. Baskerville TA, Douglas AJ. Interactions between dopamine and oxytocin in the control of sexual behaviour. Prog Brain Res 2008;170:277-90.
21. Giuliano F, Allard J. Dopamine and sexual function. Int J Impot Res 2001;13 Suppl 3:S18-28.
22. Rubio-Casillas A, Rodríguez-Quintero CM, Rodríguez-Manzo G, Fernández-Guasti A. Unraveling the modulatory actions of serotonin on male rat sexual responses. Neurosci Biobehav Rev 2015;55:234-46.
23. Olivier B, Chan JS, Snoeren EM, Olivier JD, Veening JG, Vinkers CH, et al. Differences in sexual behaviour in male and female rodents: Role of serotonin. Curr Top Behav Neurosci 2011;8:15-36.
24. Chan JS, Snoeren EM, Cuppen E, Waldinger MD, Olivier B, Oosting RS. The serotonin transporter plays an important role in male sexual behavior: A study in serotonin transporter knockout rats. J Sex Med 2011;8:97-108.
25. Angoa-Pérez M, Kuhn DM. Neuroanatomical dichotomy of sexual behaviors in rodents: A special emphasis on brain serotonin. Behav Pharmacol 2015;26:595-606.
26. Mos J, Mollet I, Tolboom JT, Waldinger MD, Olivier B. A comparison of the effects of different serotonin reuptake blockers on sexual behaviour of the male rat. Eur Neuropsychopharmacol 1999;9:123-35.
27. Snoeren EM, Veening JG, Olivier B, Oosting RS. Serotonin 1A receptors and sexual behavior in female rats: A review. Pharmacol Biochem Behav 2014;121:43-52.
28. Uphouse L. Pharmacology of serotonin and female sexual behavior. Pharmacol Biochem Behav 2014;121:31-42.
29. Bole-Feysot C, Goffin V, Edery M, Binart N, Kelly PA. Prolactin (PRL) and its receptor: Actions, signal transduction pathways and phenotypes observed in PRL receptor knockout mice. Endocr Rev 1998;19:225-68.
30. Evans AM, Petersen JW, Sekhon GS, DeMars R. Mapping of prolactin and tumor necrosis factor-beta genes on human chromosome 6p using lymphoblastoid cell deletion mutants. Somat Cell Mol Genet 1989;15:203-13.
31. Galdiero M, Pivonello R, Grasso LF, Cozzolino A, Colao A. Growth hormone, prolactin, and sexuality. J Endocrinol Invest 2012;35:782-94.
32. Egli M, Leeners B, Kruger TH. Prolactin secretion patterns: Basic mechanisms and clinical implications for reproduction. Reproduction 2010;140:643-54.
33. Hernandez ME, Soto-Cid A, Rojas F, Pascual LI, Aranda-Abreu GE, Toledo R, et al. Prostate response to prolactin in sexually active male rats. Reprod Biol Endocrinol 2006;4:28.
34. Drago F. Prolactin and sexual behavior: A review. Neurosci Biobehav Rev 1984;8:433-9.
35. Valente S, Marques T, Lima SQ. No evidence for prolactin's involvement in the post-ejaculatory refractory period. Commun Biol 2021;4:10.
36. Witt DM. Oxytocin and rodent sociosexual responses: From behavior to gene expression. Neurosci Biobehav Rev 1995;19:315-24.
37. Insel TR, Young L, Wang Z. Central oxytocin and reproductive behaviours. Rev Reprod 1997;2:28-37.
38. Argiolas A, Gessa GL. Central functions of oxytocin. Neurosci Biobehav Rev 1991;15:217-31.
39. University of Sydney. "Sobering effect of the love hormone." ScienceDaily. ScienceDaily, 23 February 2015. Available at: www.sciencedaily.com/releases/2015/02/150223164442.htm.
40. Pauciullo A, Ogah DM, Iannaccone M, Erhardt G, Di Stasio L, Cosenza G. Genetic characterization of the oxytocin-neurophysin I gene (OXT) and its regulatory regions analysis in domestic Old and New World camelids. PLoS One 2018;13:e0195407.
41. Blitzer DS, Wells TE, Hawley WR. Administration of an oxytocin receptor antagonist attenuates sexual motivation in male rats. Horm Behav 2017;94:33-9.
42. Stoneham MD, Everitt BJ, Hansen S, Lightman SL, Todd K. Oxytocin and sexual behaviour in the male rat and rabbit. J Endocrinol 1985;107:97-106.
43. Hughes AM, Everitt BJ, Lightman SL, Todd K. Oxytocin in the central nervous system and sexual behaviour in male rats. Brain Res 1987;414:133-7.
44. Arletti R, Bazzani C, Castelli M, Bertolini A. Oxytocin improves male copulatory performance in rats. Horm Behav 1985;19:14-20.
45. Robbins A. Androgens and male sexual behavior from mice to men. Trends Endocrinol Metab 1996;7:345-50.
46. Geisert RD, Schmelzle AL, Smith MF, Green JA. Altering rat sexual behavior to teach hormonal regulation of brain imprinting. Adv Physiol Educ 2019;43:458-66.

47. Witt DM, Young LJ, Crews D. Progesterone modulation of androgen-dependent sexual behavior in male rats. Physiol Behav 1995;57:307-13.
48. Davidson JM, Stefanick ML, Sachs BD, Smith ER. Role of androgen in sexual reflexes of the male rat. Physiol Behav 1978;21:141-6.
49. Davey RA, Grossmann M. Androgen receptor structure, function and biology: From bench to bedside. Clin Biochem Rev 2016;37:3-15.
50. McGinnis MY, Dreifuss RM. Evidence for a role of testosterone-androgen receptor interactions in mediating masculine sexual behavior in male rats. Endocrinology 1989;124:618-26.
51. Shulman LM, Spritzer MD. Changes in the sexual behavior and testosterone levels of male rats in response to daily interactions with estrus females. Physiol Behav 2014;133:8-13.
52. Giuliano F, Allard J, Compagnie S, Alexandre L, Droupy S, Bernabe J. Vaginal physiological changes in a model of sexual arousal in anesthetized rats. Am J Physiol Regul Integr Comp Physiol 2001;281:R140-9.