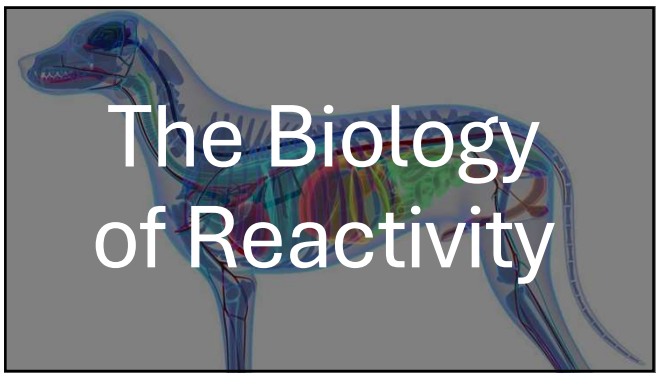
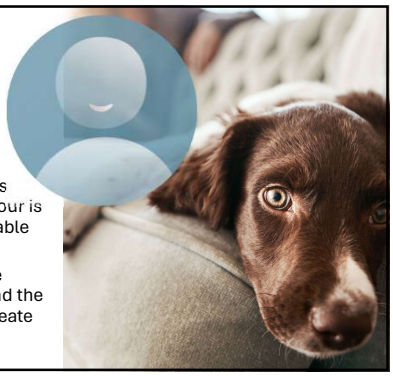


1

In Today's Webinar

- Reactivity is a behaviour
- Understanding what happens internally to elicit the behaviour is critically important in being able to modify the behaviour
- Today we will look at how the brain, the nervous system and the endocrine system work to create the perfect storm

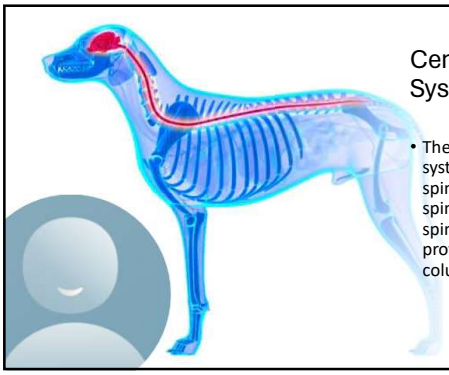


2

Terminology to Become Familiar With

- Nervous System - The nervous system includes the brain, spinal cord, and a complex network of nerves. This system sends messages back and forth between the brain and the body. The brain is what controls all the body's functions

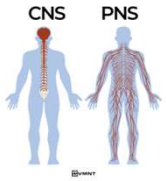
3



Central Nervous System

- The central nervous system is the brain and spinal cord – not the spinal column, but the spinal cord which is protected by the spinal column.

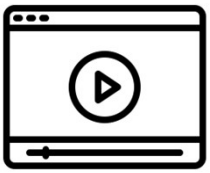
4



Peripheral Nervous System

- a network of nerves that runs throughout the head, neck, and body. It carries messages to and from the central nervous system

5



Somatic Nervous System

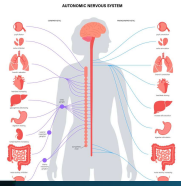
- The somatic nervous system consists of nerves that go to the skin and muscles and is involved in conscious activities.
- Sensory neurons take in information to the CNS
- motor neurons then take information from the CNS to the muscle fibres
- This is the reflex arc

6

7

Autonomic nervous system

- the division of the peripheral nervous system that regulates involuntary visceral functions such as heartbeat and smooth muscle contraction. The autonomic nervous system is divided into sympathetic and parasympathetic divisions.

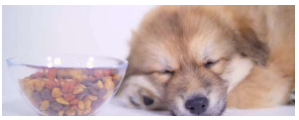


8

Sympathetic nervous system

- Involuntary part of the nervous system that increases heart rate, blood pressure, breathing rate, and pupil size. It also causes blood vessels to narrow and decreases digestive juices.

9

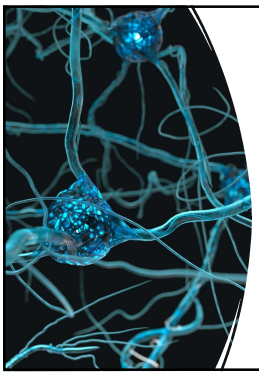


Parasympathetic nervous system

- The part of the nervous system that slows the heart, dilates blood vessels, decreases pupil size, increases digestive juices, and relaxes muscles in the gastrointestinal tract.

10

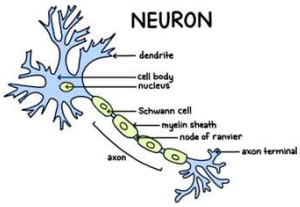
11



Neurons

- Nerve cells that send messages all over your body to allow you to do everything from breathing to talking, eating, walking, and thinking.
- The 3 types of neurons are motor neurons, sensory neurons, and interneurons.

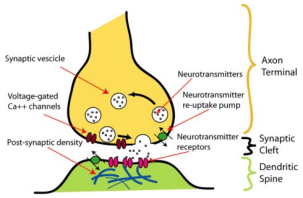
12



13

Synaptic Cleft

- There is a small gap between the axon terminal of the presynaptic neuron and the membrane of the postsynaptic cell, and this gap is called the synaptic cleft.



14

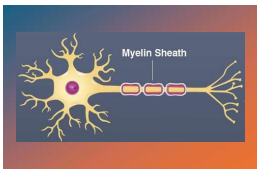
Action Potential

- Neurones communicate with each other via electrical signals known as action potentials. They are brief changes in the voltage across the membrane due to the flow of certain ions into and out of the neurone.
- Like a Mexican Wave, or Chinese whispers

15

Action Potential

16



Myelin Sheath

- Myelin's best-known function is to increase the rate at which information, encoded as electrical charges, passes along the axon's length
- Healthy myelin sheath cells mean a healthy brain
- 1) Sleep. Animal studies suggest that sleep increases the amount of oligodendrocyte precursor cells (OPCs) in the body, which can lead to increased myelin formation. ...
- 2) Exercise. ...
- 3) Socializing and New Experiences. ...
- 4) Learning New Complex Skills. ...
- 1) Fish/DHA (Brain) ...
- 2) Vitamin D. ...
- 3) Vitamin C. ...
- 4) Iodine.

17

Neurotransmitters

- Chemical messengers responsible for carrying, boosting and modulating signals between neurons.
- The total number of neurotransmitters is not known, but is likely to be well over 100 (Kovács, 2004)

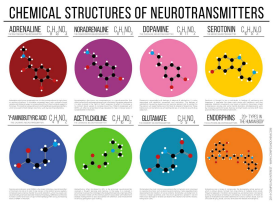
1. **Excitatory neurotransmitters**: Stimulate an action potential norepinephrine, epinephrine—aka adrenaline— histamine, Glutamate
2. **Inhibitory neurotransmitters**: Decrease probability of an action potential. Examples include oxytocin endorphins serotonin and GABA.
3. **Excitatory and inhibitory neurotransmitters**: These can have both effects depending on the receptors. Examples are acetylcholine and dopamine.

18

Neurotransmitters and Reactivity

- Dogs with aggression problems also show unusual levels of neurotransmitters, These are the chemicals that carry messages from one nerve cell to another including serotonin, dopamine, and the monoamines.
- Anxious and fearful dogs show the same imbalances in neurotransmitters. Even without the benefit of high-powered chemical analysis systems, animal behaviourists have long recognized the link between anxiety and anger and often speak of "fear-based aggression." Coren, 2009

19



20

Norepinephrine, epinephrine – Adrenaline

- Epinephrine has slightly more of an effect on your heart, norepinephrine has more of an effect on your blood vessels. Both play a role in your body's natural fight-or-flight response to stress and have important medical uses as well.
- Noradrenaline deals with responses to stress, danger and/or threats. It stimulates the central nervous system to trigger arousal, alertness, vigilance and attention in the presence of a trigger.
- Aggression can be maintained by various self-reward factors, including a positive feedback loop whereby the more aroused and reactive the dog becomes, the more adrenaline is released, leading to more arousal and reactivity. This can also lead to increasing tunnel vision – the dog becomes less aware of peripheral stimuli, while becoming increasingly focused on the eliciting stimulus (Dobson, 2012)

21

Dopamine

- Dopamine works with the prefrontal cortex and helps with behaviour modification as it is a 'feel good' chemical that also plays a part in motivation.
- The D4 receptor gene regulates dopamine levels.
- A mutation in the dopamine D4 receptor gene (DRD4) in humans is linked to ADHD behaviours. A study in German shepherds found that dogs with the same genetic mutation showed significantly higher scores in the activity-impulsivity dimension of the dog-ADHD Rating Scale than dogs without this allele (Hejjas et al., 2007) so reactivity may be linked with a dogs desire to receive a 'dopamine hit'
- "Low levels of dopamine make people and other animals less likely to work for things, so it has more to do with motivation and cost/benefit analyses than pleasure itself." (Buckley, 2012).

22

Serotonin

- Serotonin is responsible for emotional states, bonding behaviours and regulates mood balance alongside the hypothalamus.
- It also plays a role in regulating heart and lung function, sleep-wake cycles, behaviours, awareness of pain, appetite, body temperature and movement.
- Aggressive dogs with higher levels of aggression were found to have lower serotonin levels in their saliva (Gobbo et al. 2021)

23

Glutamate

- Glutamate is an excitatory neurotransmitter with several types of receptors found throughout the central nervous system
- Glutamate release triggers production of glutamine.
- Studies found increased plasma glutamine and γ-glutamyl glutamine (γ-Glu Gln) in fearful dogs across breeds (Puurunen et al 2018)

24

Endorphins

- Endorphins are chemicals (hormones) your body releases when it feels pain or stress.
- Endorphins help relieve pain, reduce stress and improve your sense of well-being
- The release of neurotransmitters during reactive episodes can be intrinsically rewarding for the dog
- Frustration and tension release are often significant self-rewards, along with the post-adrenaline, post-endorphin feel-good factor, relief from anxiety after removing threats and psychological satisfaction of winning challenges and agenda conflicts. (Dobson, 2012)

25

Oxytocin

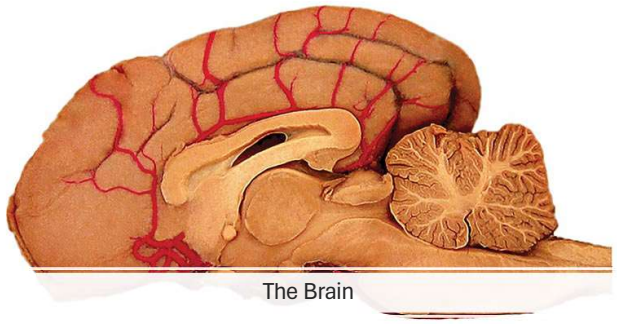
- Oxytocin is released in response to activation of sensory nerves during labour, breastfeeding and sexual activity. In addition, oxytocin is released in response to low intensity stimulation of the skin, e.g., in response to touch, stroking, warm temperature, etc.
- Oxytocin plays a key role in social cognition, in social behaviours
- A number of studies have shown that when dogs and humans interact with each other in a positive way (for example cuddling) both partners exhibit a surge in oxytocin, a hormone which has been linked to positive emotional states (Marshall-Pescini et al 2019)

26

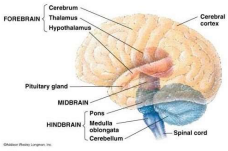
GABA

- In the mature brain it works as a inhibitory neurotransmitter
- When it interacts with the receptors of a neuron, it makes it less likely to fire an action potential or to release neurotransmitters
- Increased GABA can have sedentary effects
- Alcohol and benzodiazepines increase activity of the GABA receptor

27



28



How the Brain Works Creates Reactive Behaviours

- The largest area of the brain goes by many names: forebrain, cerebrum, cerebral cortex or 'thinking brain'.
- The midbrain functions as a relay system, transmitting information necessary for vision and hearing. It also plays an important role in motor movement, pain, and the sleep/wake cycle.
- This is also known as the 'survival brain' and is where the fight or slight reflex originates.
- This part of the brain controls fine motor skills, the regulation of blood flow, pulse rate, processes rewards and is where reflexes for reactivity and reactiveness come from.

29

The Forebrain and Reactivity

- It is responsible for memory, learning, temperament and intelligence, and is responsible for taking in information and translating from the senses.
- It also relays sensory information the hypothalamus which controls the release of pituitary hormones and regulates behavioural responses

30

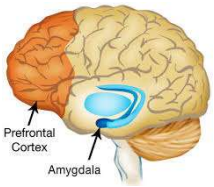
The Amygdala

- The survival and defence area
- Multisensory integration for survival
- Takes in sensory, neurological and endocrinological information
- integrates it with internal information (disease, pain, sleep state, gut information - hormonal and neurological)
- Also integrates with experience and learning history
- This is where 'perception' is formed and where the individuality of the dog is evident

31

Amygdala to Prefrontal Cortex

- Then passes the information to the prefrontal cortex – responsible decision making, integrates emotional info and sensory info with previous experiences, learning history, long term memory,
- Then we get an action – potentially
- Amygdala and prefrontal cortex have really strong neurological associations , very well connected



32

Amygdala to Posterior cingulate cortex

- Posterior cingulate cortex in cerebral cortex connected to amygdala and is responsible for first impressions
- Structural and functionally well connected – info passes back and forth , especially important for threat assessment, essential for survival

33

The striatum

- In the brain, the striatum controls, regulates and modulates perception
- Gives the dog a chance to think about their response – do we start getting ready to react, or do we react straight away? The striatum determines how strong, if any, the response is
- Motor reactivity – how reactive is the motor cortex going to be when presented with the info. The striatum tells the motor cortex what to do

34

Hypothalamus

- Receives sensory input (along with the amygdala, which are both at the base of the brain) close to incoming neurons
- Hypothalamus connected to a lot of other parts of the brain, and has a lot of neurovascular connections
- Senses a threat, increases heart rate, blood pressure, decreases vascular tone and increases blood going to muscles, this happens before you've decided what the decided response will be

35

Hypothalamus

- Positive and negative stress triggers our hypothalamus to release cortico-trophic releasing hormone to the anterior pituitary which then produces adrenocorticotropic hormone (ACTH). ACTH travels in the blood to the adrenal glands, located just above the kidneys.
- Hypothalamic – pituitary – adrenal axis – cortisol released from adrenal glands HPA-Axis.
- All the body's non-essential processes are downgraded when cortisol is released, such as the immune system and digestion.

36

HPA Axis

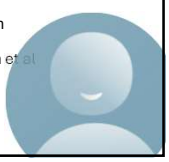
- The parasympathetic nervous system, which is responsible for rest, healing and recovery, basically begins to shut down.
- The sympathetic nervous system takes over, stimulates the medulla and there is an increase of adrenaline and norepinephrine produced.
- We will see an increased heart rate, breathing changes, dilated pupils, less eating, increased salivation, a rise in blood pressure, hyper-awareness, and hyper-vigilance. The body will also begin producing excess glucose in case the body needs excess energy to flee a situation (as a part of the 'flight' response

37

38

So, Basically....

- The information comes in to both the amygdala and the hypothalamus
- The amygdala talks to the prefrontal cortex while the hypothalamus tells the body which hormones to release, which then will impact how the dog responds.
- Again, sensory input and maternal care will alter the gene expression (epigenetics) of the glucocorticoid receptor, impact the firing of the HPA-axis which results in a change in behavioural phenotype in adulthood (Kaffman & Meaney, 2007)
- So, turning on or off receptors in the synaptic cleft resulting in activation of action potentials, or no activation.
- And this is linked with an increase in aggression (Aubin-Horth et al 2012)
- Think of a puppy farms impact on reactivity later in life.



39

40

Neural Pathways

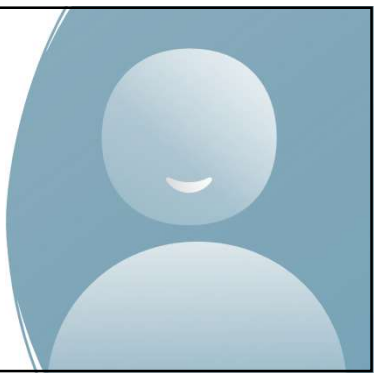
- Our dogs can learn new things because of neural plasticity, which is the ability to form new pathways for neurotransmitters to follow within our brain.
- The more a behaviour and response occur, the more efficient the synapse between the neurons in the brain will become, and the more this neural pathway will get used in the future.

41

42

Canine Social Deprivation Syndrome

- Results from a stressful prenatal or neonatal environment, insufficient early socialization, or a particularly traumatic environmental event in a dog's life
- It can be a contributing factor in the display of aggressive behaviours as a dog ages.
- Social Deprivation Syndrome will occur when the social needs of a dog are not met, especially in the crucial socialisation period between approximately 4 and 12 weeks of age.



43

- This is when the brain and nervous system are developing, the capacity for learning develops and positive experiences are crucial in contributing to the development of a healthy and well-balanced dog. Dogs suffering from this syndrome may be more likely to display aggression towards other dogs and people as they age if interventions and support are not put in place.

44

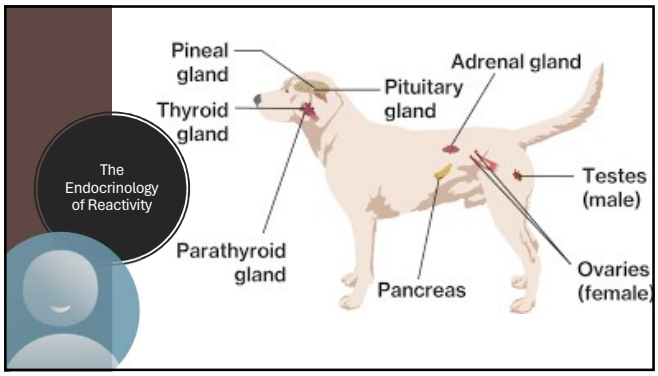
- Puppies who have been removed from their mother at too early of an age, kept separate from their littermates, or who have not experienced contact with humans during these weeks all may find communicating with others more challenging.
- There can be serious and long-lasting consequences on the behavioural and physiological development of the dog.
- Social and non-social stimulation is important for normal puppy development…puppies learn how to interact with and play other dogs appropriately, they require exposure to sounds, textures, handling, and experiences that are presented in a positive way.
- At this early age, and for dogs of all ages really, the absence of one negative experience can far outweigh the effects of many positive ones – so ensuring that experiences with novelty are done gently and positively is important. Dogs who lack experiences, positive or negative, can be at risk of developing canine social deprivation syndrome as they get older.

45

The Endocrine System

- The endocrine system is the system of glands, each of which secretes a type of hormone into the bloodstream to regulate the body. While powerful, the endocrine organs are relatively small.

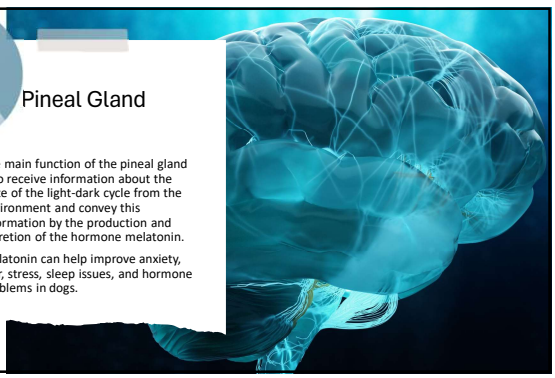
46



47

Pineal Gland

- The main function of the pineal gland is to receive information about the state of the light-dark cycle from the environment and convey this information by the production and secretion of the hormone melatonin.
- Melatonin can help improve anxiety, fear, stress, sleep issues, and hormone problems in dogs.



48

49

Adrenal Gland

- The two adrenal glands are located on the top of each kidney. The adrenal cortex produces glucocorticoids (e.g., cortisol) that help the body control blood sugar, increase the burning of protein and fat, and respond to stressful stimuli, such as fever, major illness, and injury.

The adrenal medulla produces epinephrine (adrenaline)

increases heart rate, opens airways to improve oxygen intake, and increases blood flow to muscles.
The adrenal medulla usually secretes epinephrine when one is scared, excited, or under stress.
The adrenal medulla also secretes norepinephrine, but this hormone is more related to maintaining normal activities as opposed to emergency reactions.

50

Cortisol

- A dog's perception of events as the levels of cortisol increases in their bodies changes – the amygdala will recognise the elevated cortisol in the blood
- Pain from an undiagnosed health issue can cause an increase in cortisol and in turn affect our dog's perception of events in a negative way.

51

Testes

- As in humans, unneutered male dogs and cats have twin reproductive glands, called testes, which produce the hormone testosterone. Testosterone helps the young male develop and then maintain his sexual traits.
- Testosterone increases confident, competitive aggression directed specifically at other male dogs (Hart and Eckstein, 1997)
- Circulating testosterone can also increase the likelihood of dogs being very distracted by other dogs or showing signs of high arousal and frustration, particularly around bitches in season. However for a number of reasons castration does not always reliably eliminate these problem behaviours (Hart and Eckstein, 1997).

52

Ovaries

- The female reproductive glands, the ovaries, produce estrogen and progesterone.
- Increasing levels of oestrogen can cause them to appear irritable or annoyed. In some young female pups, this can cause them to start resource guarding
- Results demonstrated a negative effect of low progesterone levels on premenstrual mood symptoms, such as aggressive behaviour and fatigue in healthy reproductive-age women.

53

When A Reactive Dog is Exposed to a Trigger

- When a dog is confronted with something that makes it uneasy, this is the chemical that guides its attention to it and puts the dog on alert.
- When the fight or flight response is triggered and the sympathetic nervous system is activated, noradrenaline is released. The body's heart rate and breathing rate increases and there is an increase in blood glucose levels (to provide energy to muscles in the case that 'flight' needs to occur).
- Chronic exposure to high levels of noradrenaline can result in gastrointestinal difficulties, anxiety, and muscle tension.

54

Using Dopamine in Reactivity Recovery

- Dogs WANT dopamine, finding the right way to gain dopamine hits will likely lead to an increase in that behaviour
- Increased levels of this neurotransmitter increase the motivation level in a dog and make positive training possible as it drives a dog to repeat rewarded behaviour.
- Finding rewards that our dogs absolutely love can make modifying behaviour much easier.
- Using a favourite toy or an especially tasty type of treat or food when working with a stressed, anxious, fearful or reactive dog and help to increase dopamine levels, reduce stress and push the dog to continue trying a task or behaviour.

55

Serotonin in Reactivity Recovery

- . This neurotransmitter can be affected by diet, which has a direct impact on an animal's mood.
  Nutritionally derived serotonin is something the body relies heavily on, so a poor diet that lacks tryptophan results in lower serotonin levels and increased mental instability.
  In many species, dogs included, depletion of serotonin in the body has been linked with aggression.
  Increasing serotonin in these cases may help to decrease the aggressive behaviour, as it has a strong inhibitory effect on emotional responses and impulsive behaviour, alongside positive behaviour modification techniques.

56

Using GABA in Reactivity Recovery

- Valerian root helps relieve anxiety and tension in your dog by raising GABA levels.
- GABA supplements can help to calm an anxious dog

57

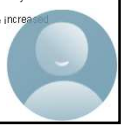
So, In Summary, When We Think of Reactivity….

- What happens to make dogs sensitised?
- What happens to push dogs over threshold?
- What physiological changes occur?
- What chemicals are released
- Why does this all matter?

58

References

- Corren, S. 2009. https://moderndogmagazine.com/articles/pill-popping-pups/
- Dobson, J.E.N.N.I.F.E.R., 2012. Human-directed canine aggression. *Veterinary Times*, *42*(45), p.14.
- Gobbo, E. and Zupan Šemrov, M., 2021. Neuroendocrine and cardiovascular activation during aggressive reactivity in dogs. *Frontiers in veterinary science*, *8*, p.683858.
- Hart BL, Eckstein RA The role of gonadal hormones in the occurrence of objectionable behaviours in dogs and cats. Appl Anim Behav Sci. 1997; 52:331-44
- Hejjas, K., Vas, J., Topal, J., Szantai, E., Ronai, Z., Székely, A., Kubinyi, E., Horváth, Z., Sasvari-Szekely, M. and Miklósi, A., 2007. Association of polymorphisms in the dopamine D4 receptor gene and the activity-impulsivity endophenotype in dogs. *Animal genetics*, *38*(6), pp.629-633.
- Kovács, G.L., 2004. The endocrine brain: pathophysiological role of neuropeptide-neurotransmitter interactions. *EJIFCC*, *15*(3), p.107.
- Marshall-Pescini, S., Schaebs, F.S., Gaugg, A., Meinert, A., Deschner, T. and Range, F., 2019. The role of oxytocin in the dog–owner relationship. *Animals*, *9*(10), p.792.
- Puurunen, J., Tiira, K., Vapalahti, K., Lehtonen, M., Hanhineva, K. and Lohi, H., 2018. Fearful dogs have increased plasma glutamine and γ-glutamyl glutamine. *Scientific Reports*, *8*(1), p.15976.
- (kaffman & Meaney, 2007)
- And this is linked with an increase in aggression (Aubin-Horth et al 2012)



59