

- **emotions** are *affective responses* to stimuli (either internal or external)
  - a positive or negative reaction to a perceived, remembered, or imagined object, event, or circumstance, accompanied by a subjective feeling
  - states of “feeling” / “affect” consisting of a pattern of cognitive, physiological, and behavioral reactions to events (external or internal)
    - Our external emotional responses are an important form of social communication

- Nature versus nurture:
  - Innate biological factors may be at play
    - more afraid of “primal” stimuli (heights, water, spiders, snakes)
      - than more modern threats (guns, cars)
  - Learning through previous experiences also important

emotions based in large part on **perceptions** of sensory stimuli from environment

## **fundamental difference between sensation and perception:**

**Sensation:** physical activation of a sensory system  
detection / experience of an internal or external stimulus  
(light striking retina, sound activating receptors in cochlea, etc)

**Perception** - assigning a value or meaning to sensations  
interpretation / understanding “conscious”  
(requires neural processing that occurs only in cortex)

There are only **2 basic / “primitive” emotions:**

*“pleasure” and “anxiety”*

physiological signs of intense pleasure?

arousal / activation of sympathetic division of ANS

heart rate / blood pressure, steroid hormone

release, “butterflies” in stomach

physiological signs of intense anxiety? same

**physical** feeling of:

seeing police lights vs. winning lottery

both same physical arousal sensation

but different emotion

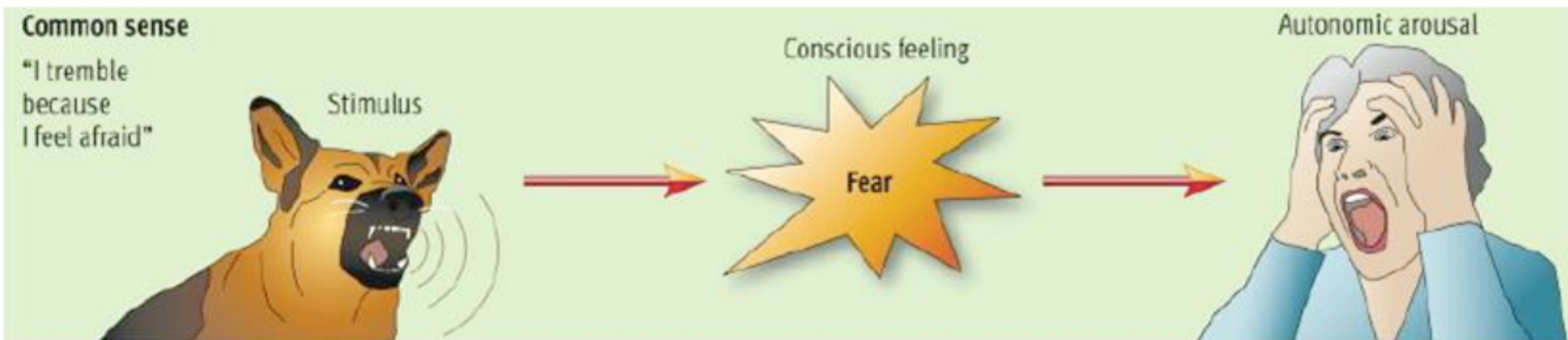
*..so, identical **sensations** (arousal) > different emotional **perceptions***

- **Positive < > Negative:** Helps us to *approach* (love / happiness) or *withdraw* (fear / disgust) from appropriate situations in life
  - Negative emotions (fear) focus attention so that we can respond with a focused set of responses.
  - Positive emotions may serve to broaden our thinking and behavior

# Theories of emotion:

“Common sense”: your body reacts because you feel emotions

Event > emotion > physiological arousal



**James – Lange theory**: you feel emotions after your body reacts

Event > physiological arousal > interpret physiological changes > emotion

People with Spinal Injuries have more “cognitive” emotions

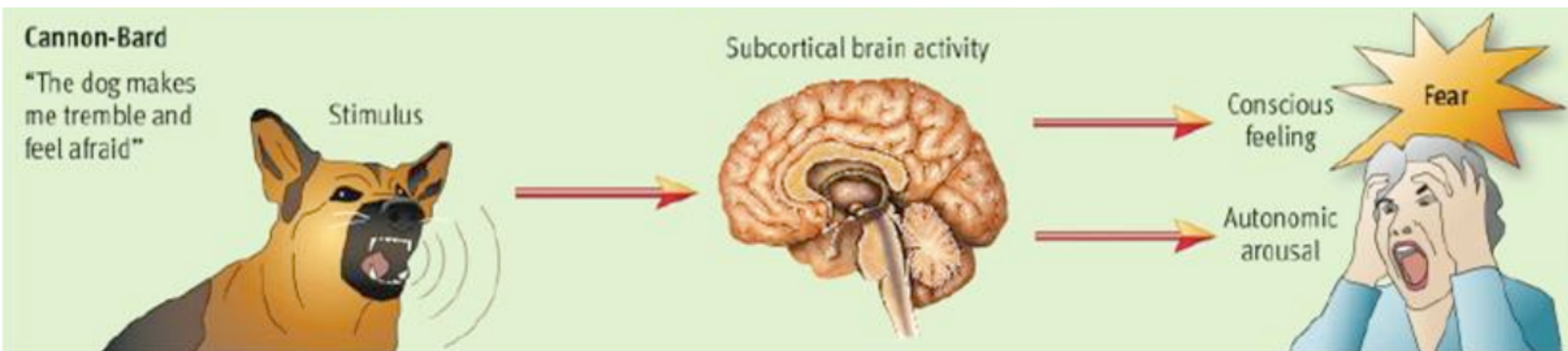
**Facial Feedback hypothesis**:

experience emotions due to position of your facial muscles  
smiling makes you feel happier  
frowning makes you feel sadder



# Cannon – Bard theory: the event causes both arousal and emotion at the same time

Event > (physiological arousal / emotion)





**Joseph LeDoux's theory:** different emotions rely on different combinations of body and brain reactions and interpretations

Event > (brain & body reactions / memories & interpretations) > emotion

**The Schacter – Singer experiment:**

Subjects told that they are receiving a vitamin & vision test  
it's really epinephrine

Half wait with “manic” confederates > feel *happy*

Half with “angry” > feel *angry*

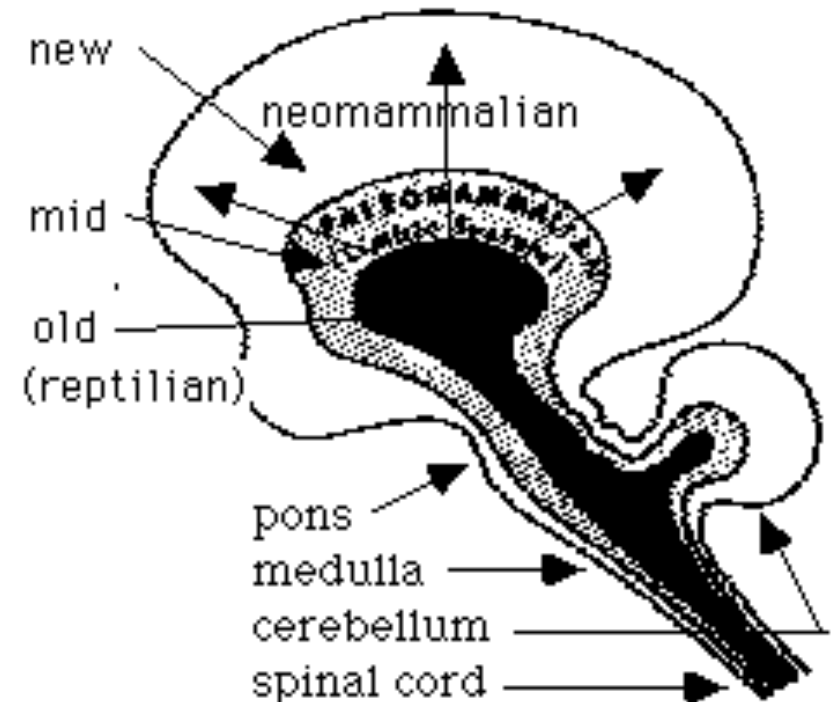
whether told about drug in advance or not, no difference

interpreted arousal AND environment as EMOTION

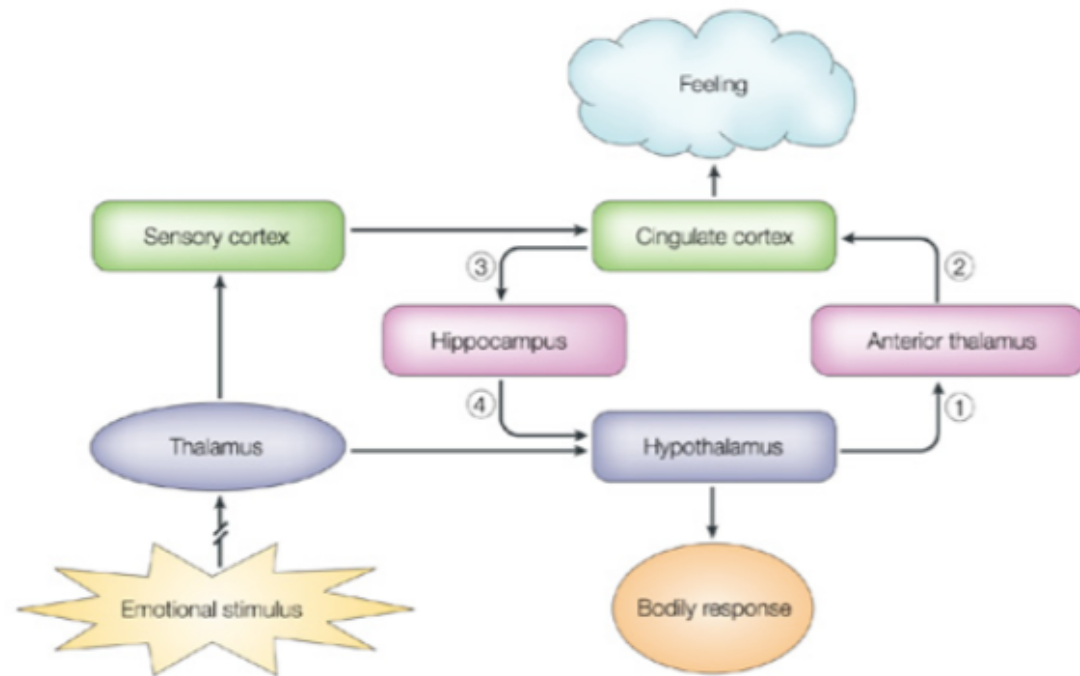
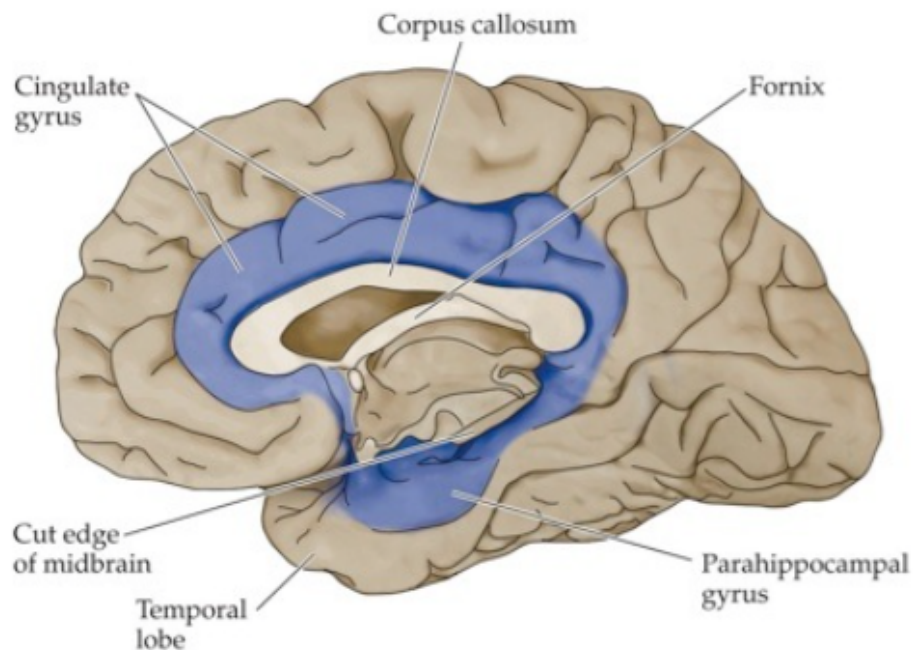


# James Papez (1937) drew up rough outline of the neuronal circuit for emotional expression:

- sensory info from primary sensory neocortical areas > “limbic areas”
  - Limbic = “border” between primitive brainstem / complex neocortex
  - paleocortical ring of primitive cortical structures



- sensory info from primary sensory neocortical areas > “limbic areas”
  - > cingulate gyrus (paleocortex)
    - > structures in the temporal lobe (hippocampus and amygdala)
      - > hypothalamus (LH / mammillary bodies)
        - > anterior (medial dorsal) thalamus (cortical relay station)
          - > cingulate gyrus
            - > neocortex (especially PFC)
- reciprocal connections throughout
- connections between hypothalamus (bodily arousal) and cortex (sensations / perceptions / memories) and amygdala (context)



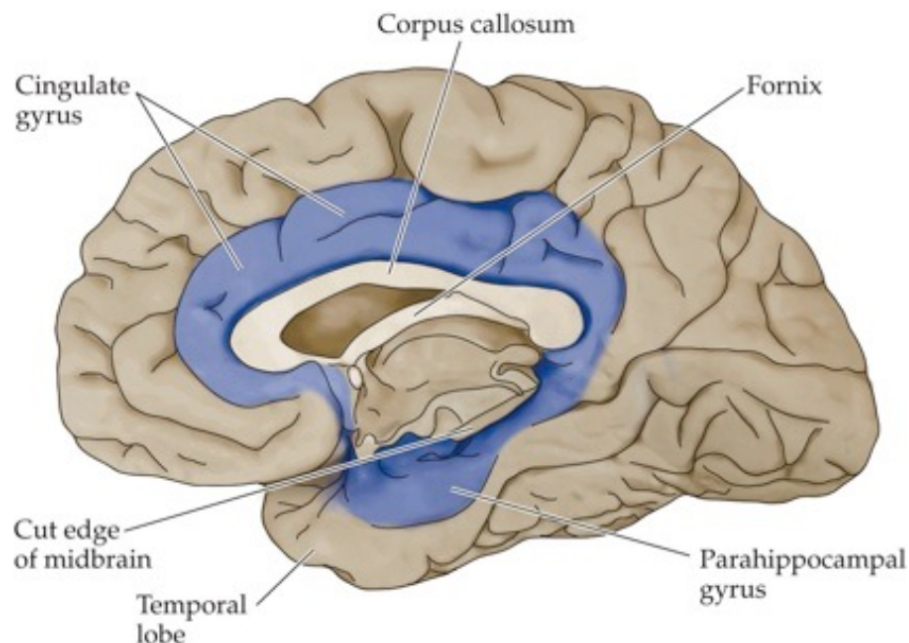
## ROLE OF CORTEX:

- “conscious” thought / “perception” most likely requires a *cortex*
  - Does a cockroach *perceive*? Or does it “just” *sense* (like a S-R robot)?
- different types of cortex mediate different levels of “conscious” awareness:
  - paleocortex (“old / primitive”) deep / close to brainstem
    - all vertebrates (only kind for reptiles)
    - 3-4 layers perception of primal / basic emotions (pleasure / anxiety)

## ROLE OF CORTEX:

- most important (paleo)cortical area for emotional processing is the *cingulate gyrus*
- role of paleocortex in the Papez circuit is to interpret level of bodily arousal as a basic emotion
  - quickly tells us if a situation is “good” or “bad”

...so, paleocortex - the primitive cortical structures – mediates fast, primitive emotions

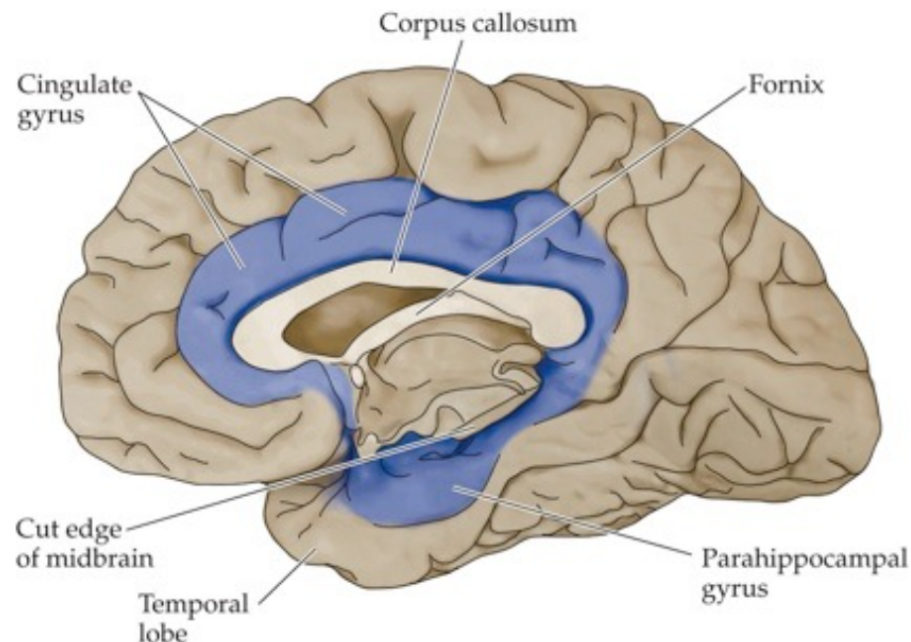


## Neocortex:

- neo (“new”) covers brain
  - restricted to “higher” animals (more complicated - mammals)
  - 6 layers adds more complexity to emotional perception
  - responsible for bringing emotion “conscious” to interpret / control

most important neocortical area for emotion is PFC (more later)

how “level of bodily arousal” is interpreted by neocortex depends upon:  
memories and aspects of immediate environment (context) -  
“appraisal”



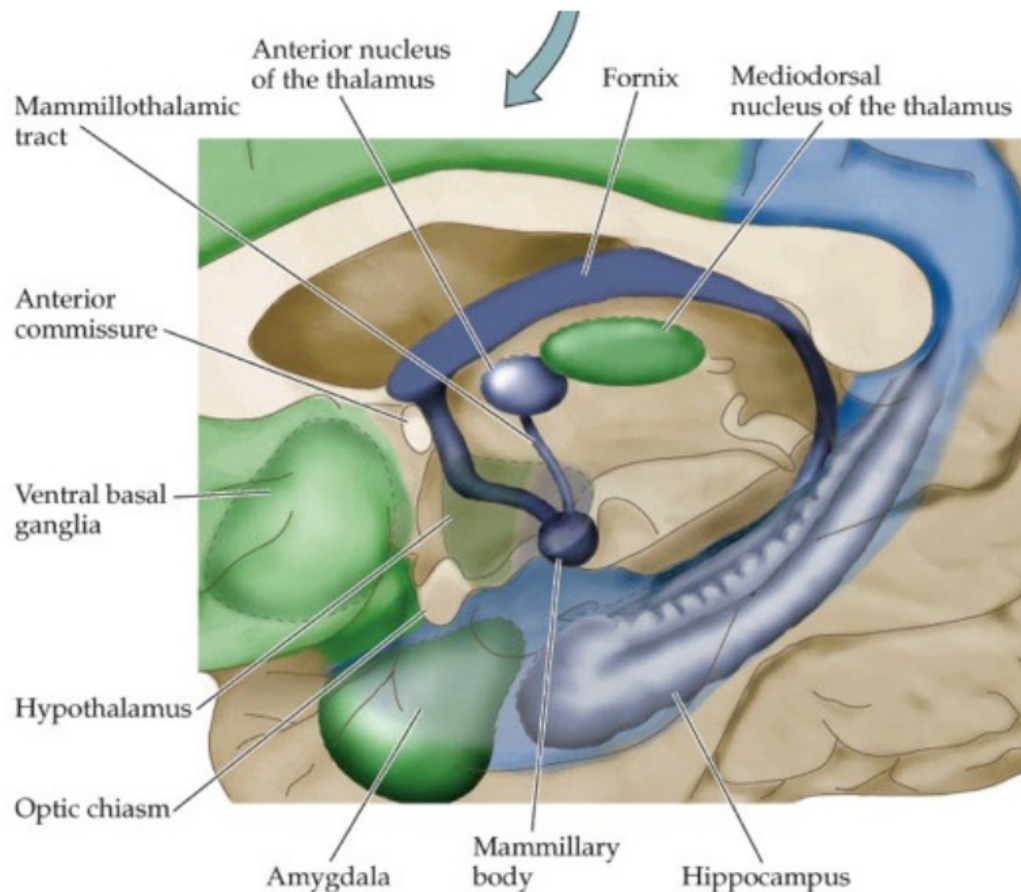
State trooper lights in your mirror:

- paleocortex (cingulate) quickly says - “bad”
- neocortex (PFC) decides between trying to outrun cop / pull over
  - accesses memories - last time, just got a warning
- neocortical processing generates a more “conscious” experience and allows for control of the emotion...

**SO, cortex interprets the arousal signals received by the Papez circuit..... but, what causes these bodily changes in response to sensory stimuli?**



- **HYPOTHALAMUS** is a subcortical structure
  - sits at top of brainstem
  - “control center of the Autonomic Nervous System” (ANS)
- 2 divisions:
  - sympathetic - fight / flight
  - parasympathetic - rest / digest





- **HYPOTHALAMUS**

- *orchestrates* release of hormones
- extension of brainstem Reticular Activating System
- widespread ins / outs - in addition to inputs from cortical sensory areas
- it also receives direct inputs from sensory neurons (retina)
  - allows for quick processing
- hypothalamic processes all below consciousness (“subconscious”)
  - cortex not required, but connected to neocortex by way of the paleocortex

- hypothalamic connections w/in the limbic system allow for bodily expression of emotion in response to stimulus
  - remember: Papez circuit is a 2-way street
    - allows hypothalamus to be influenced by cortex and cortex to be influenced by hypothalamus....
  - SO, by connecting various brain areas... **Papez circuit provides the anatomical basis of emotional perception / expression**
- to sum up....sensations influence hypothalamus >
  - ANS produces an aroused or calm state >
    - which (along with context) the cortex interprets as “emotion”...
    - so, level of bodily arousal & emotion intimately tied

# Experiments designed to study emotions

- 2 categories - see what happens when:
  - turn an area ON
  - turn an area OFF
- focal brain lesions / focal brain cooling  
simulate inactivity
- electrical stimulation simulates activity
  - various drugs can do both

- Stimulation of lateral hypothalamus

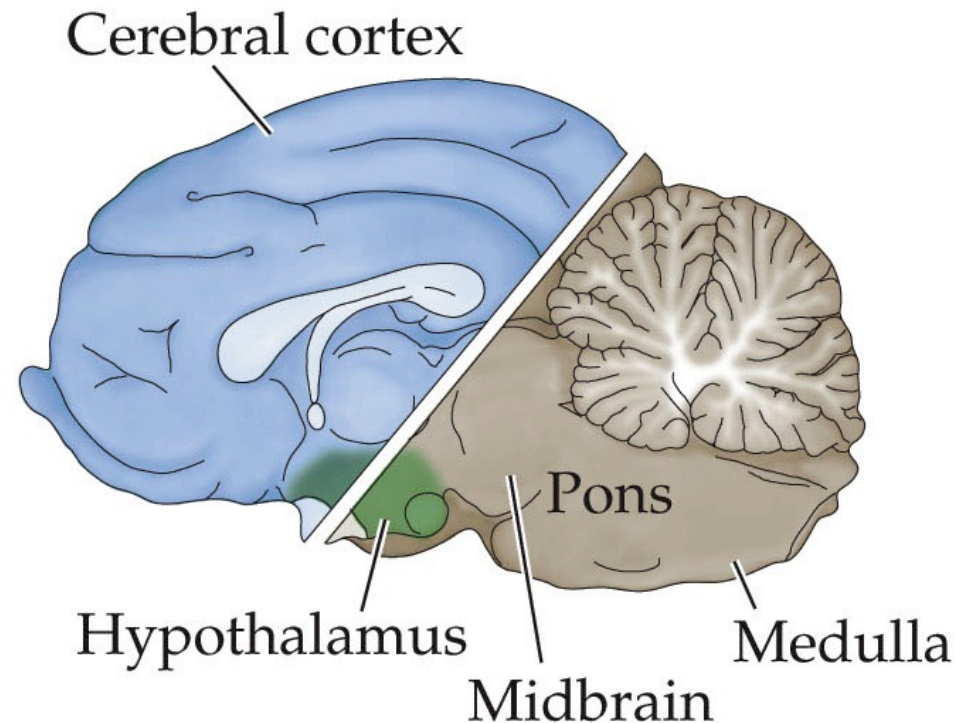


- Stimulation of lateral hypothalamus
  - evokes a coordinated set of arousal responses
    - looks like “anger”:
      - arched, back hair standing up,
      - hissing, increased blood pressure
      - activity in LH produces all of these behaviors associated w/ arousal
- Lesions / inactivation of LH > opposite (placid / calm)

...so, hypothalamus takes various inputs and integrates them into organized sets of arousal responses

- Other experiments showing role of hypothalamus:
  - opened up back of cat's head so they could make cuts that would disconnect the brain from the body at various levels
- Decortication - disconnects cortex from the body but leaves hypothalamus connected by way of spinal cord

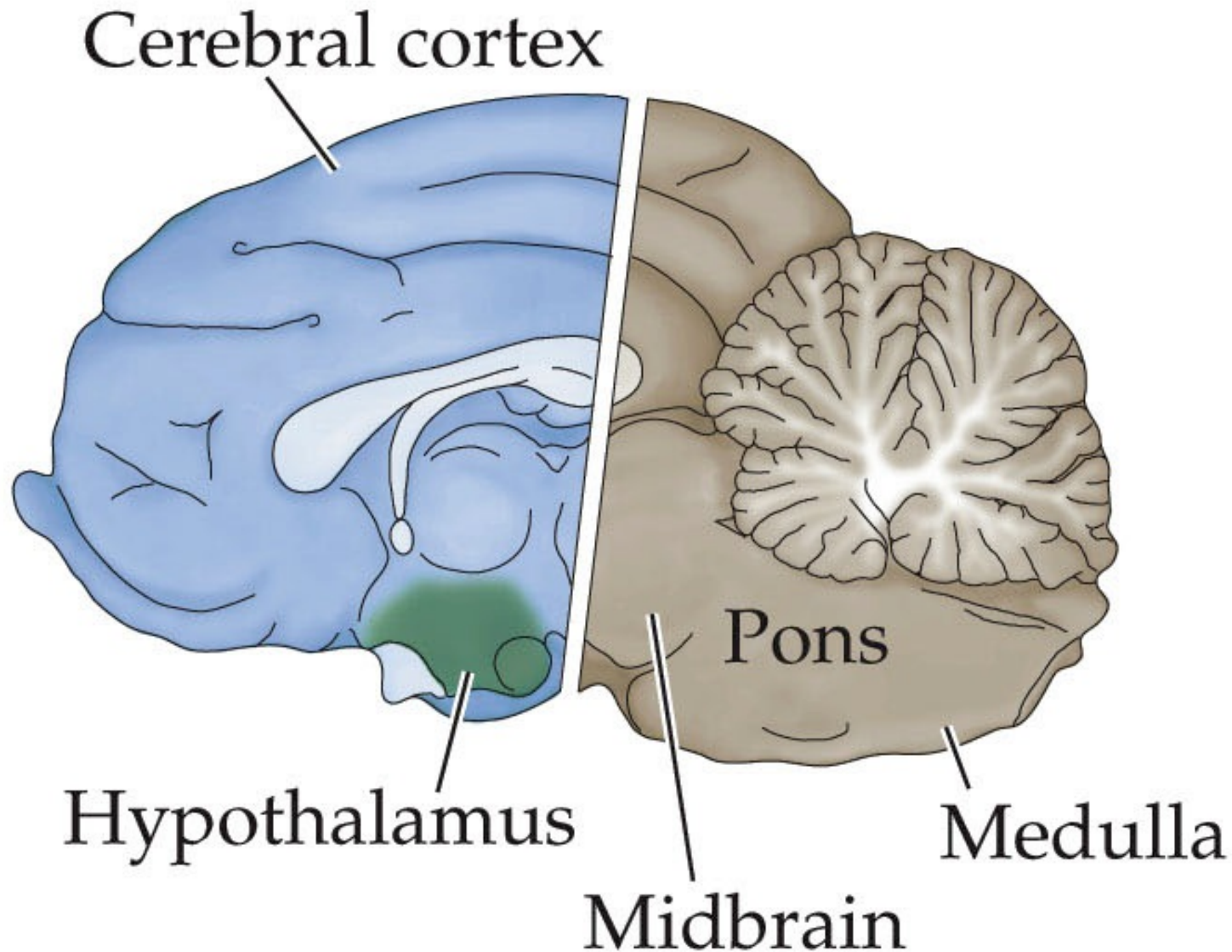
(B) "Sham rage" remains



- Decortication produces behavior known as: “Sham” rage
  - bodily arousal:
    - arched back hair standing up, hissing, increased blood pressure
    - “untargeted” attacks, (bite selves)
      - occurs spontaneously or with mild stimulus (petting)
- no communication between hypothalamus and cortex
  - animal is not consciously aware of the arousal
    - no cortex - petting may be sensed by nervous system, but not “perceived”

# Lower cut: disconnect hypothalamus from body

(A) No "sham rage"





- eliminates sham rage: won't respond to petting
- only responds to strong, painful stimuli = spinal reflexes
  - fractionated, uncoordinated set of arousal responses
- demonstrates that hypothalamus contains circuits for:
  - coordinated bodily expression of various emotional behaviors
- so.... hypothalamus modulates basic emotional state by producing states of bodily arousal
  - (sympathetic) vs. calm (parasympathetic)

# **PREFRONTAL CORTEX (neocortical) 2 major roles...**

**1. determines “appropriateness” of physically expressing level of arousal**

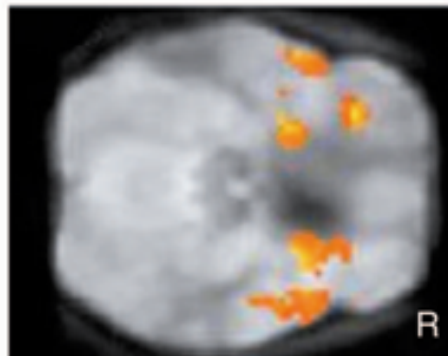
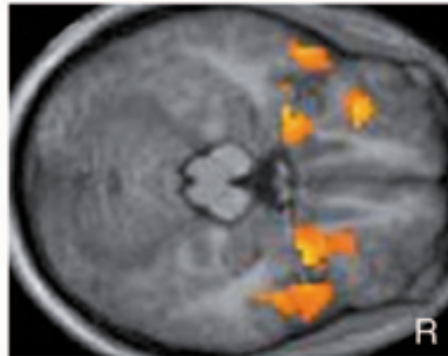
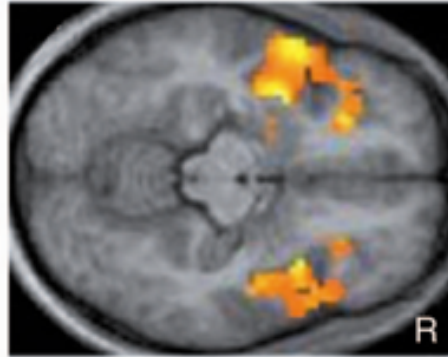
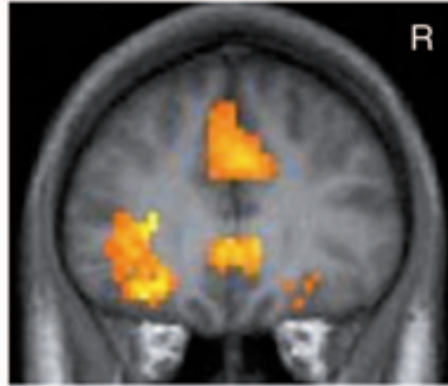
- activity in PFC cortex inhibits inappropriate responses to primal emotions
  - “uptight” center of brain
- underactivity.... inappropriate responses to situations (major symptom of schizophrenia)

# PREFRONTAL CORTEX (neocortical) 2 major roles...

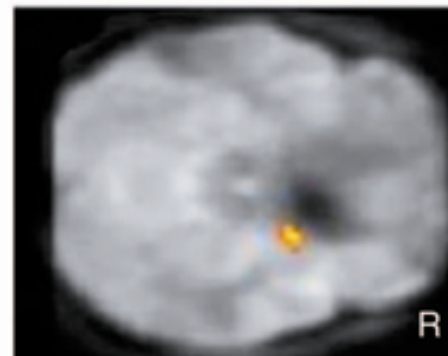
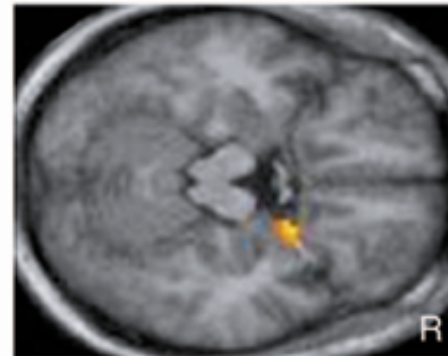
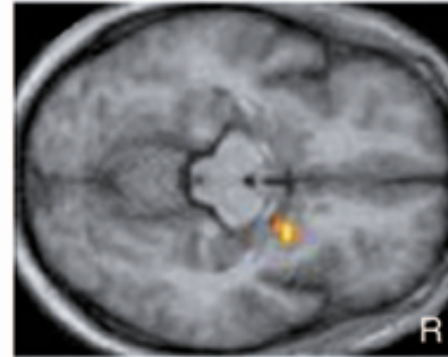
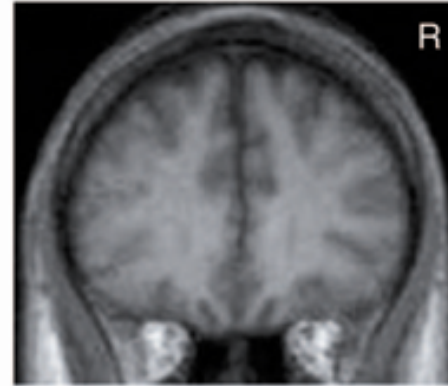
2. determines “target” of arousal response (directs emotion)

- sham rage - untargeted attacks
- brain imaging / brain stimulation experiments suggest that overactivity of PFC may lead to states of over-arousal / anxiety (perpetually uptight about smallest things)
- main role of prefrontal cortex is to *inhibit*
  - Subjects watched porn while brain is imaged
    - Amygdala and hypothalamus active
    - Told to “*inhibit arousal*”
      - frontal lobe more active
      - amygdala & hypothalamus less
  - Sociopath brain scan – very little frontal activity
    - free will / accountability?

Healthy controls

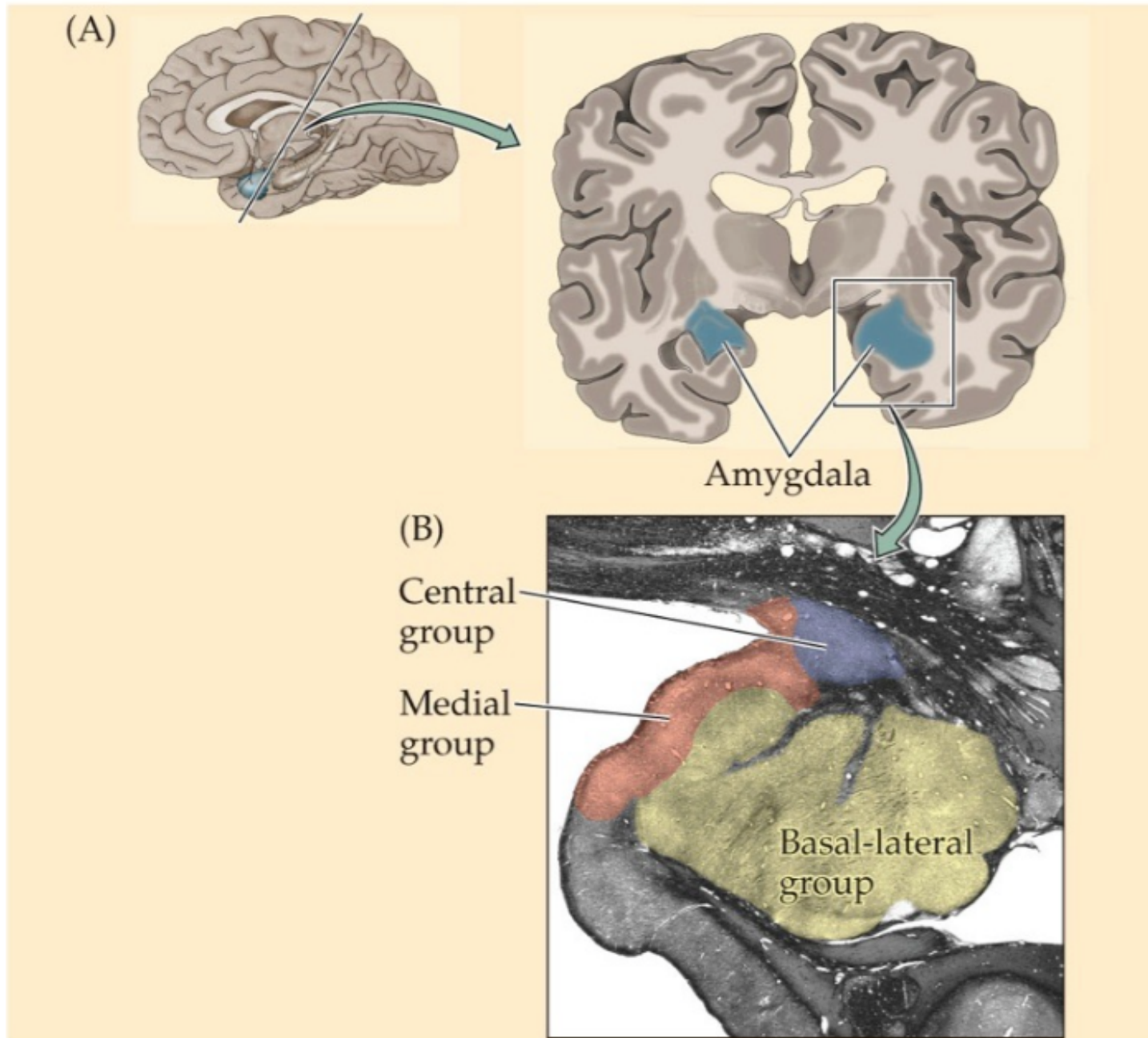


Psychopaths



- another brain area experimented with:
  - CINGULATE GYRUS (paleo) like PFC, increased activity associated with high anxiety
    - cingulectomy - newer psychosurgical technique for reducing severe anxiety...
- mostly, drugs are used now
- other limbic areas have been studied in this regard
  - one of 1<sup>st</sup> brain lesion experiments (early in century)
    - bilateral removal of a monkey's temporal lobe
      - produced a group of behaviors known as Kluver-Bucy syndrome:
        - tameness / flat affect (expressionless) / hypersexual
    - severe temporal lobe epilepsy in humans, which results in excessive stimulation of the temporal lobe, produces symptoms opposite of Kluver-Bucy:
      - hyperemotionality / melodramatic, loss of sex drive
        - stimulation / lesions of an area produces opposing behaviors

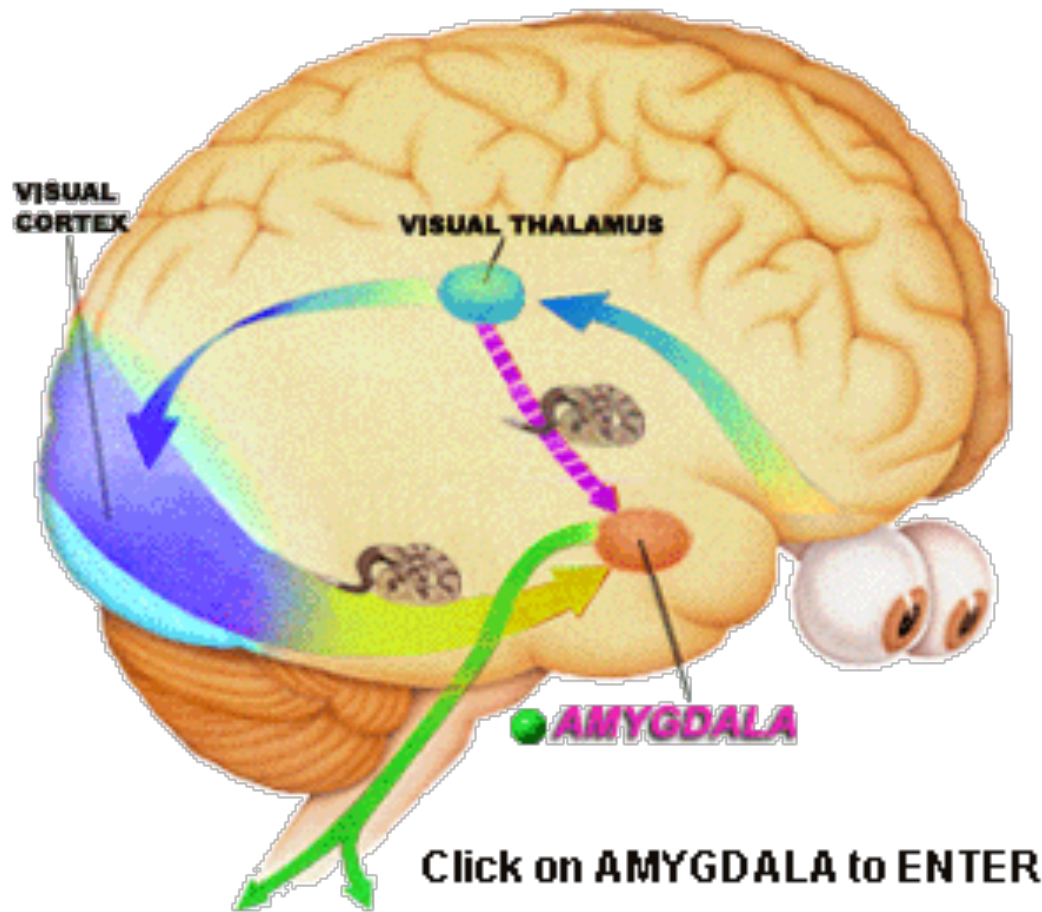
- pointed out a structure earlier that's buried in the temporal lobe next to the hippocampus
  - AMYGDALA - responsible for emotional learning / memory



- Many emotional responses are learned (phobias / old pictures / perfume)
- EMOTIONAL MEMORY is how events or stimuli come to be associated w/ various emotional states
  - associative type of learning (classical and operant conditioning)
- proper functioning of amygdala critical for emotional learning & memory
- fear is easiest to study experimentally - startle responses easy to recognize and define



Two “emotional” pathways for sensory information:  
one that goes to cortex first (slower)  
one that goes directly to the amygdala (faster)





Emotions can occur outside of our conscious awareness

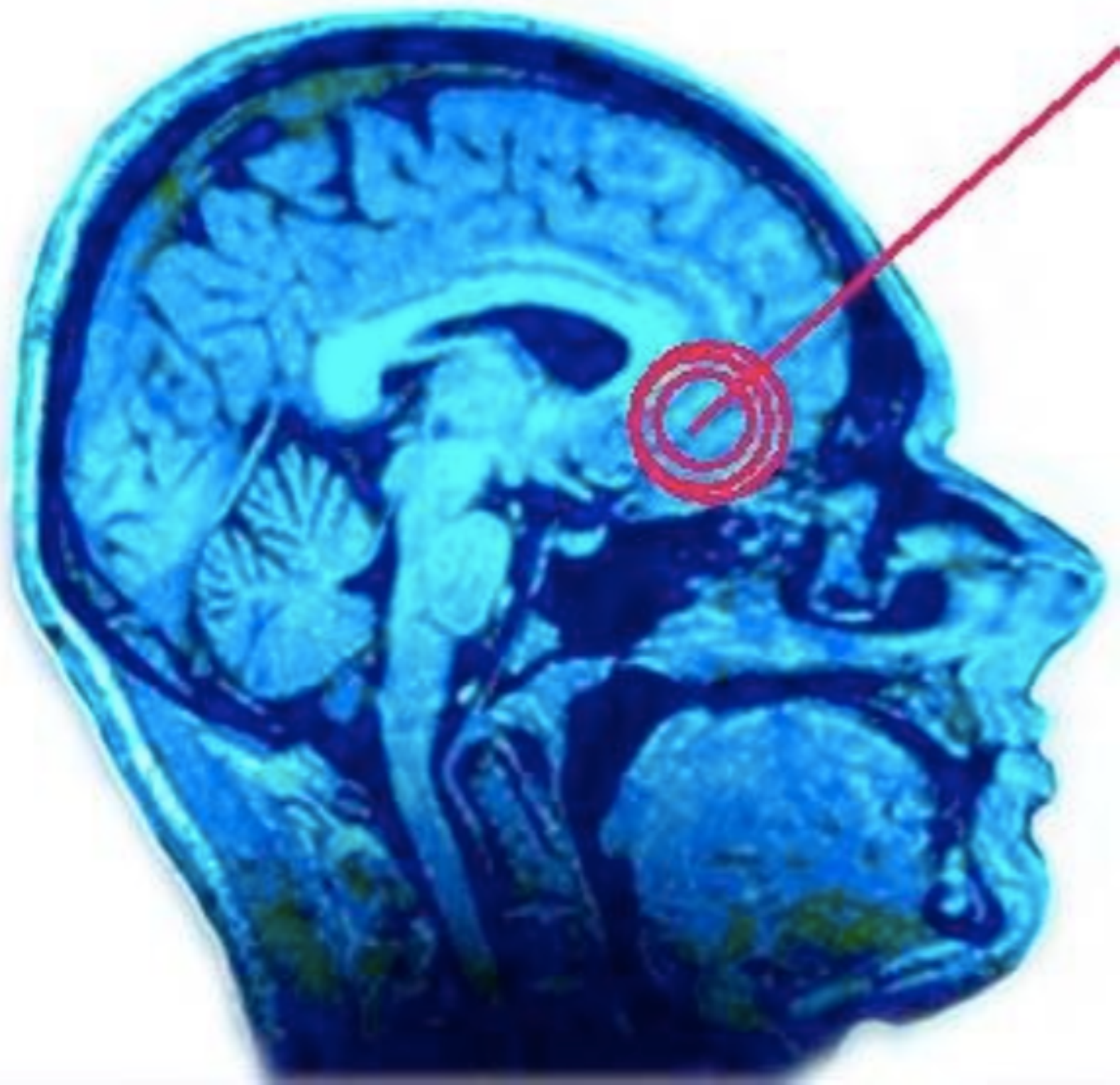
- People with damage to the hippocampus form emotional responses without remembering learning them
  - involves classical conditioning

- John Watson 1920 - baby Albert / rat
  - now, emotional L/M studied with “classical fear conditioning”
  - rat is in a cage: tone (CS) paired with shock (US)  
(associative - tone predicts shock)
  - rat learns to respond to sound in absence of shock response
    - (CR) = sympathetic (fight / flight) activation
      - “freezing” normal response to threat “if I don’t move, the animal that’s trying to eat me won’t see me....”

rat has learned to respond emotionally to a previously neutral stimulus in that tone becomes associated with “fear”

- amygdala inactivation / lesions block fear conditioning (will never learn)
- stimulation - intensifies ???
- *to summarize, amygdala is responsible for learning emotional responses to events or stimuli*

- ICSS - subject has control... electrical stimulation of certain limbic areas > perception of “pleasure”
  - structures deep w/in hemispheres:
    - nucleus accumbens
    - septal nuclei (basal forebrain)
    - hypothalamic fiber pathways
    - medial forebrain bundle
    - brain stem RAS
    - ventral tegmentum
- How do we know it causes pleasure?



- ICSS experiment: Rat is allowed to turn brain electrodes on / off by pressing lever  
each time briefly stimulates the area  
a rat in this situation will press a lever 120x / min....until physically exhausted  
never get enough - takes precedence over any other reward:  
food, sex, endure pain

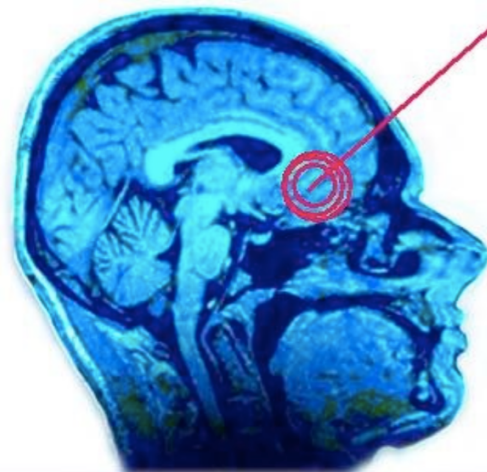


- activity in these areas is perceived as intense “pleasure”
- suggests role for these structures in neural “reward” system:
  - do something biologically good
    - good for species (sex) OR organism (eating)
  - rewarded by feeling good...
  - likely to repeat behavior in future
    - Thorndyke’s *law of effect*
- similarly, do something bad, less likely to repeat
- brain is training itself via operant conditioning - ensures survival

- primitive emotions may have evolved as a survival mechanism
- these same structures also sensitive to various drugs (chemicals that affect mental state - natural or synthetic)
  - either: modulate NT activity (up / down) or mimic a NT
- some work directly on limbic structures, “tricking” system into perception of pleasure



- highly studied example:
  - Nucleus accumbens (deep limbic brain structure – ICSS)
    - heavy monoaminergic input (from brainstem RAS)
      - ne, da, 5-ht
    - MDMA / cocaine / amphetamine: enhance NT activity in nucleus accumbens
      - inhibit reuptake / mimic NTs = increased activity, intense pleasure
        - presumably similar to “reward” via ICSS...



TO SUMMARIZE: activity in several limbic areas associated w/ perception of “pleasure”

- led to idea of a reward system
- chronic “artificial” stimulation of this system makes it harder to activate normally
  - raises threshold?
    - leads to addiction (just to feel normal)