• **The issues**
  - Innate or learned?
  - Voluntary or involuntary? (Conscious/ unconscious)
  - Adaptive behavior or communication?
  - Emotional expression vs. emotional experience.
  - Do animals have emotions?

• **Measuring emotions**
  - Behavior (emotional display)
  - Autonomic system (heart rate, breathing, sweating.) The polygraph.
  - Endocrine system (hormone levels, E, NE)

• **The four theories**
  - *Common Sense* View
    - Perception of bear
    - Feeling of fear
    - Physiological reactions
  - James-Lange View
    - Perception of bear
    - Physiological reactions
    - Feeling of fear
  - Canon-Bard View
    - Perception of bear
      - Feeling of fear
      - Physiological reactions
  - **Modern Biopsychological view (LeDoux)**
    - Perception of bear, feeling of fear, physiological reactions all at once
    - Most popular

• James-Lange Theory
  - Feelings *after* physiological reactions ...

**Limbic system**
- Limbic system: network of structures involved in the experience and expression of emotions.
  - Limbic cortex (cingulate and part of prefrontal cortex)
  - Formix
  - Mammillary body (part of hypothalamus)
  - **Amygdala**
  - Hippocampus

**Modern Theory (LeDoux): two pathways**
2 routes to the amygdala

**Fast ('gut' reaction):**
stimulus - thalamus - amygdala - response

**Slow ('cognitive'):**
stimulus - thalamus - primary sensory cortex - association cortex - ... - hippocampus - amygdala - response

Auditory Fear Conditioning

**Scientific study of emotions: fear conditioning**
- Fear can be innate or learned.
- **Conditioning:** association between a neural cue (tone, a.k.a. *conditioned stimulus*), and a relevant negative stimulus (a.k.a. *unconditioned stimulus*, electrical foot shocks).
- **Measure:** freezing behavior when hearing the tone.
- **Abolished by lesions of the (lateral) amygdala.**
- Amygdala involved in the acquisition (learning) of fear.

Auditory Fear Conditioning

Good animal model: many studies have shown that the pathways for auditory fear conditioning are similar in rats and humans.

Extinction of fear: VentroMedial prefrontal cortex

**Extinction: repeated presentation of the tone alone, after learning**
- Extinction is NOT forgetting
- Emotional learning (in rats) is permanent
- VentroMedial Prefrontal cortex is actively involved in extinction of fear (rats and humans)

Emotion: the amygdala

- **The lateral nucleus of the amygdala**
- **Inputs:** cortex (primary and association), thalamus and hippocampus.
- **Outputs:** striatum (reinforcement learning) and prefrontal cortex (planning, extinction)
- **Involvement:** emotional learning, reward perception. Auditory fear conditioning. Conditioned taste aversion.
- **Expressions of emotions**
  - Behavioral
  - Autonomic
  - Endocrine

- **The central nucleus of the amygdala (CE)**
- **Inputs:** internal amygdala
- **Output:** hypothalamus, midbrain (PAG), pons, medulla
- **Involvement:** lesion and stimulation studies show that CE is involved in the expression of negative emotions and emotional learning. Also involved in long-term stress (PTSD?)
- Brain regions that receive inputs from CE
  - Specifically:
    - Lateral hypothalamus
• Ventral tegmental area
• Locus coeruleus (NE)
• PGA
• Facial motor nuclei

Amygdala and fear
• **Amygdala and fear: evidence**
  • Animal: stimulation of the hypothalamus: fear/attack expression (sham rage)
  • Human: stimulation of amygdala (during neurosurgery): fear experience
  • Human damage to amygdala: decrease in startle response and emotional memory. Alzheimer’s patients memory for emotional events is impaired and correlated with amygdala damage.
  • Human fMRI: amygdala is active during the perception of danger.

Aggressive behaviors
• The *expression* of aggressive behaviors is genetically programmed. Species specific (hissing, biting, shouting...) In human, it can be learned.
• 3 kinds of aggressive behaviors
  • Threat behaviors
  • Defensive behaviors
    • (both threat and defensive): towards same species. Emotional, social hierarchy
  • Predation
    • Towards other species: not emotional.
• The *cause* of aggressive behavior is partly genetic (sexual/reproductive bases), and partly environmental (learning, past experiences)

Neural control of aggressive behaviors
• Serotonin: inhibits aggression and risk taking behaviors.
  • LOW: Risk taking over-aggression; HIGHT: risk averse 'shy'
• Measure levels of 5HT metabolite in CSF (5HIAA) in rhesus monkeys.
• Humans: Prozac is effective at decreasing aggressive and antisocial behaviors.
• Human: twin studies show a genetic basis.

Emotion: the ventral-frontal cortex
• **Aggression:** the frontal cortex
• **Anatomy**
  • Ventromedial prefrontal cortex = Orbito-frontal cortex + cingulate cortex
  • Base of the frontal lobes.
• **Inputs:** thalamus, temporal cortex, Ventral Tegmental Area, *amygdala*
• **Outputs:** hippocampus, hypothalamus, *amygdala*
• Role: control of complex emotions. The last part of the brain to mature (~10-12 years old)
Phineas Gage
- **Evidence and history**
  - 1800's: Phineas Gage
  - Accidental destruction of the (orbito) prefrontal cortex.
  - Cognitively normal (e.g. intact learning, normal intellectual abilities). Childish, irresponsible, selfish, inappropriate behaviors.

Ethics and moral judgement
The trolley Dilemma: saving lives of others

Lobotomies
- 1935: Becky the monkey
- About 50,000-100,000 cases worldwide
- 1960's: SSRIs and anti-depressants. A pharmacological solution to psychotic behaviors.
- Lobotomies are banned in some countries (Russia), still legal but rarely used in Europe and US (Neurosurgery for mental Disorders)
- Summary; vmPFC: takes high level sensory information, matches them to social standards and plans emotional actions.
- Lesions -> social judgments can be done in theory, but not in practice.

QUIZ:
1. The Ventro Medial Hypothalamus is involved in maternal behaviors. **TRUE**
2. A patient with androgen insensitivity syndrome will look female. **TRUE**
3. The Ventro Medial Prefrontal Cortex is involved in **personal** moral judgments.
   Surgical lesions of the Orbitofrontal cortex is called a **lobotomy**.
4. The central nucleus of the amygdala
   B. **Is involved in the expression of emotions.**