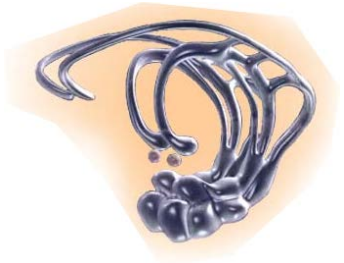
Computational Diagnostics
& Biocybernetics Unit

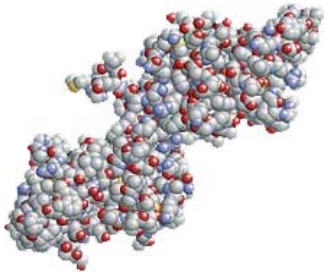
The Limbic System

**Saarland University, Saarland University Hospital,
and Saarland University of Applied Sciences**

Topics

- **Emotions**
  - Retrospective
  - Classification and Theories
  - Individual Impact
  - Communication
- **Emotion assesment**
  - Brain Areas – The Limbic System
- **Behavioural relevance**
  - Interaction with other brain areas
  - Interaction with neural messenger systems
  - Interaction with non-neural messenger systems





EMOTIONS

Psychological background

Emotions

Retrospective:

Ancient world: Philosophic approach

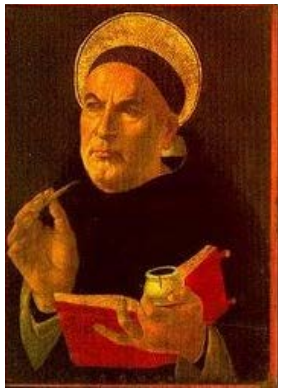
• EMPEDOKLES (ca 450 BC): 2 basic principles → Love and hate as driving forces

• ARISTOTELES (384-322 BC) wrote „De Anima“ (on the soul). He divided emotions into 2 ranks:

- Virtues
- Pleasure and reluctance driven passions

Middle ages: Clerical dogmatic approach

Mundane affects were considered to be demons. Emotions were defined as **human weaknesses** (fear, jealousy, lust) or as **divine emotions** (charity, wrath, sympathy)



AUGUSTINUS (354-430 AD): Love is the universal driving force. All passions are against nature.

THOMAS von AQUIN (1225-1279): Love is the primary emotion, intellects is the control entity

Emotions

Retrospective:

Renaissance, Barock and Age of Enlightenment: Dualism approach

DESCARTES (1596-1650): Body and Soul Dualism. Mechanical concept of the body: The brain is the domicile of the soul.
Experiences and emotions occur according to physiological principles.

KANT (1724-1804): Emotions as mental disturbances. He divides human behaviour into 3 classes:

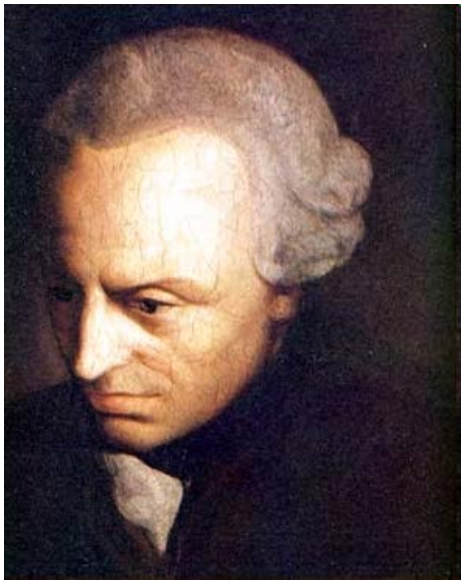
Thinking = pure rational

Drive and Action = practical rational

Sensation = power of judgement

Thinking is dominant. Emotional world is divided into affect (turbulent temporal feelings) and passion (long-term affection).

Being subject to those emotions is caused by a state of illness of the mind.



Emotions

Retrospective:

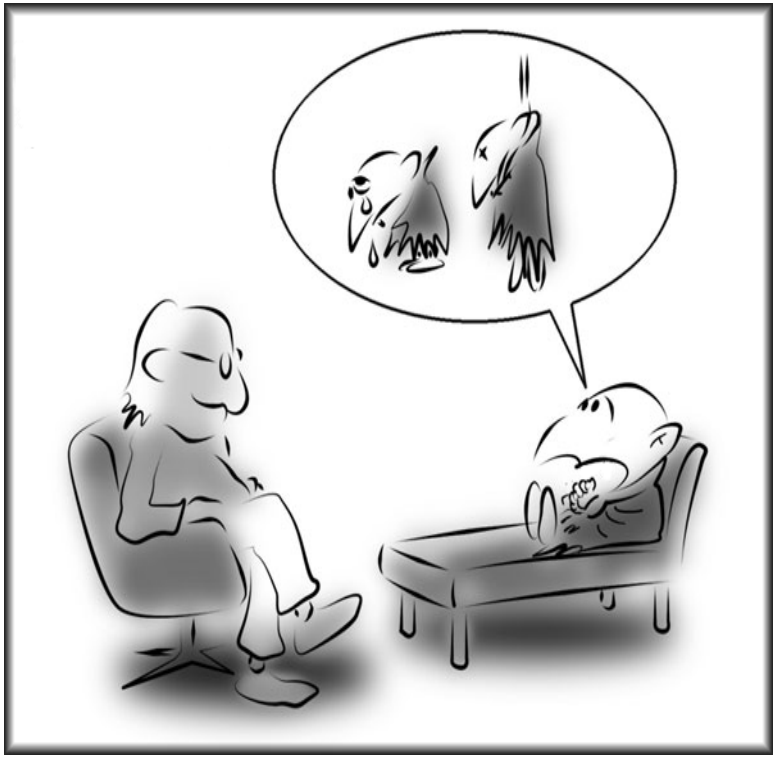
19th century: Psychology

• peripheral-psychophysiological theories: Emotions are a reaction to sensoric stimuli (JAMES).

• central-psychophysiological theories: Emotions arise from subjective elements of consciousness with physiological correlates (WUNDT).

• Psychomental theories: Emotions are simply the readiness for specific actions (BRENTANO).

• Evolution-biological theories: Emotions are phylogenetic adaptations crucial for survival (DARWIN).



Emotions

Classification:

Basic emotions trigger fight-or-flight behaviour and are communicated via facial expression:

- Anger, Disgust, Fear, Sadness
- Surprise, Curiosity†
- Happiness, Acceptance

Complex emotions arise from educational and cultural priming or association combined with the basic emotions.

- Amusement, Embarrasment, Guilt, Pride, Shame, Relief...

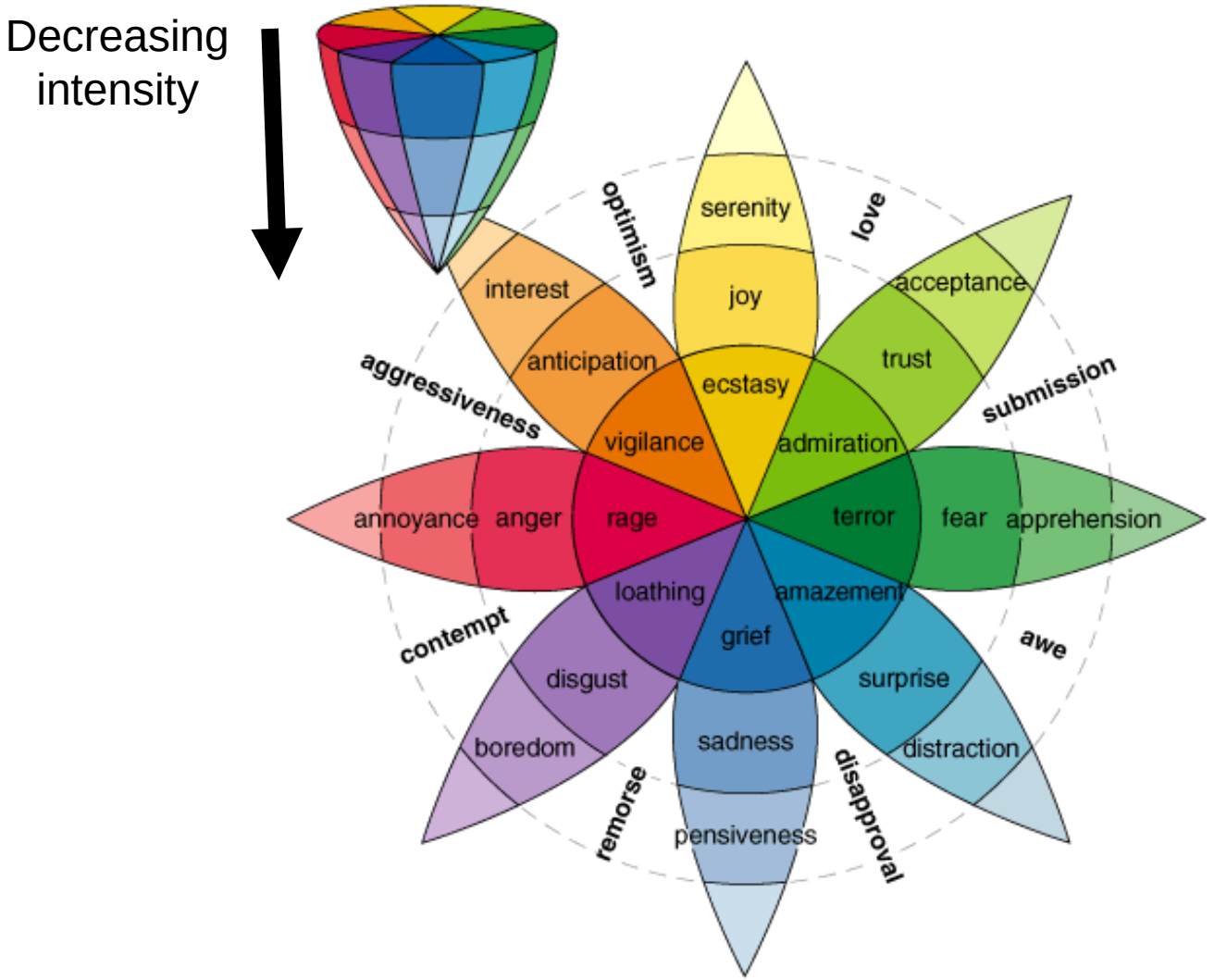
Plutchik argues for the existance of *Meta-Emotions* (emotions about emotions)

Scherer includes emotion-related states: hunger, satisfaction, pain, curiosity†

Ekman, P. & Friesen, W. V (1969). The repertoire of nonverbal behavior: Categories, origins, usage, and coding. *Semiotica*, *1*, 49–98

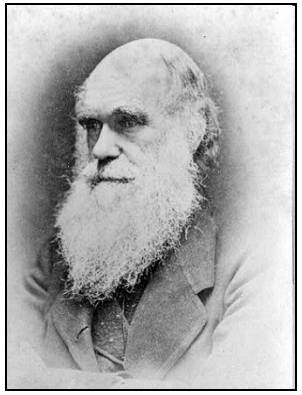
Plutchik, R. (1980). A general psychoevolutionary theory of emotion. In: Plutchik R. & Kellerman H. (Ed.). Theories of emotion. New York: Academic Press.

3D-model of basic and complex emotions by Plutchik



Emotions

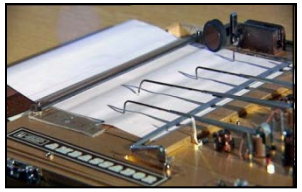
Theories:



Evolutionary Biology:

Based on Darwin: Emotions linked to behaviour crucial to the survival of men. Inherent expression and comprehension of emotions. Neglects inter-individual variability.

Psycho-Physiology:



Physical alterations in reaction to emotion: Glands, Skin, Vasculature. Neglects the origin of emotions

Behaviourist / Social-learning-theorie:

Emotions are reactions to external stimuli (reflex). Watson describes 3 innate emotional reaction patterns: **Fear** (loud sounds, loss of footing), **Rage** (loss of liberty of action) and **Love** (caress). Enlargement of reaction patterns by classical conditioning.

→ Unlikely due to inter- and intraindividual variablity of emotional reactions

Emotions

Theories:

Congnitive assessment:

Cognitive appraisal between stimulus and reaction with high interindividual variability. Not stimulus eclicts emotional response but their interpretation (additional physiological and motivational components).

Functionalist component-process-models

Emotions are by-products of different processing stages.
→ Specialization for higher-level processing
→ Behavioural regulation

- Senso-motoric stage: experience
- Schematic processing: connect / associate
- Scheme activation: compare

Emotions

Individual impact:

According to the evolution-biologist theory emotions provide innate mechanisms to cope with behaviourally important situations. Sensory might mechanisms eclict reaction patterns.

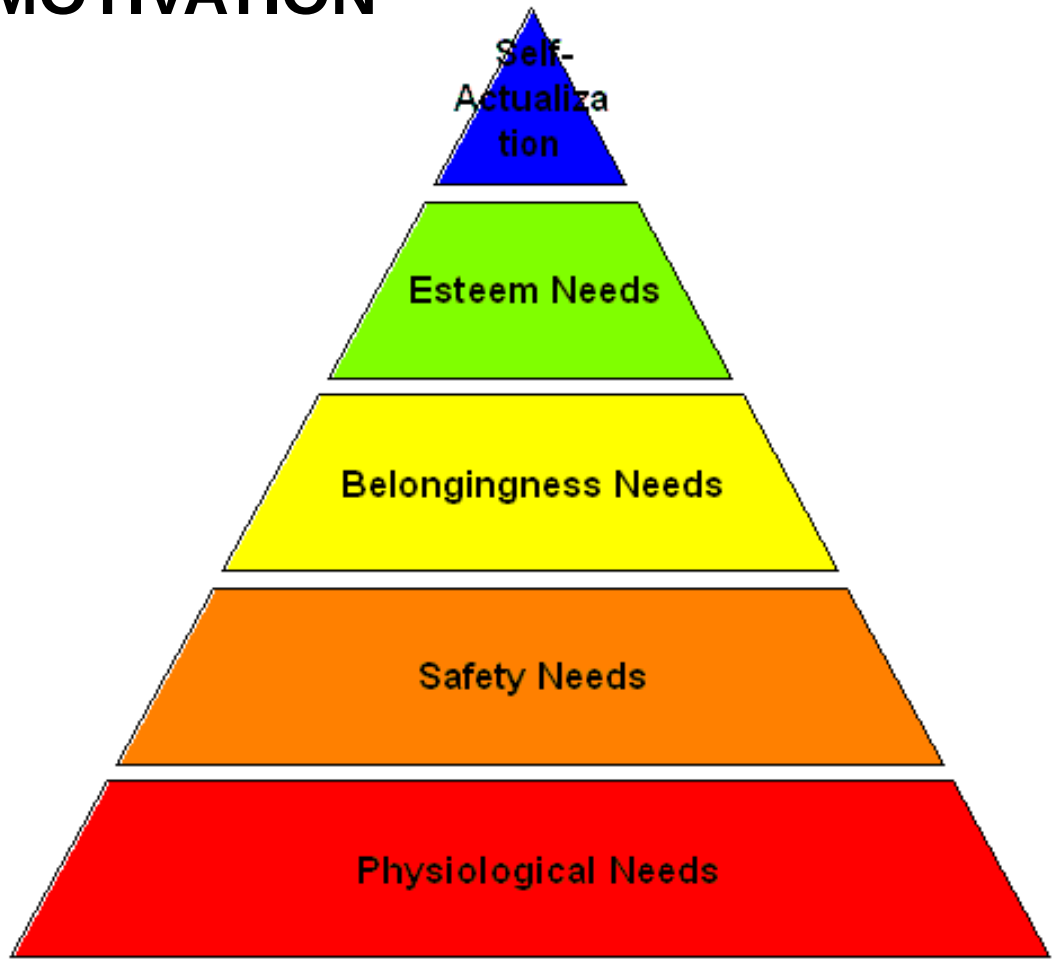
In 2005 Lidell et al.[1] discovered a direct link from the brainstem to areas responsible for the processing of aversive stimuli. This link reacts to even subliminal signals of fear, thus a high-level assessment of aversive stimuli is not always necessary.

Basic emotions eclict fight-or-flight reaction pattern

[1] Lidell et al, „A direct brainstem-amygdala-cortical 'alarm' system for subliminal signals of fear“, *NeuroImage,* 24(1):235-243

Emotions

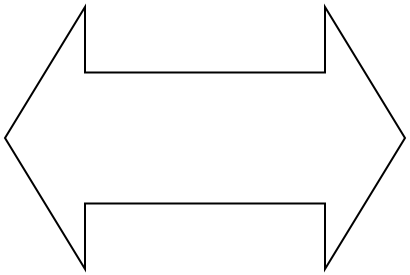
MOTIVATION



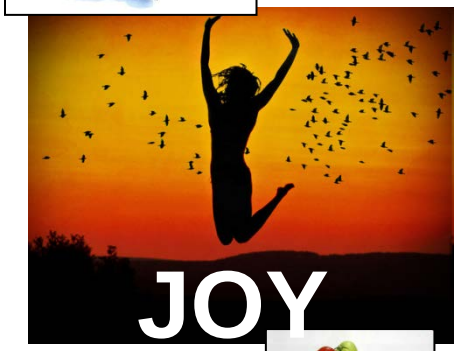
Maslow's hierarchy of needs

Emotions

PROTECTIVE



MOTIVATING



Emotions

What about curiosity?

"I have no special talent. I am only passionately curious."

Albert Einstein

Curiosity is considered being a complex emotion. It origins from an information gap, i.e., a discrepancy between what the subject knows and what one wants to know.

The object of curiosity is an unconditioned rewarding stimulus: unknown information anticipated to be rewarding. Obtaining new information carries two qualities: 1. Novelty and 2. Elation/Achievement

Curiosity thus is tightly linked to mechanisms of prediction/prediction error and of reward anticipation.

Communication – Emotions in social interaction

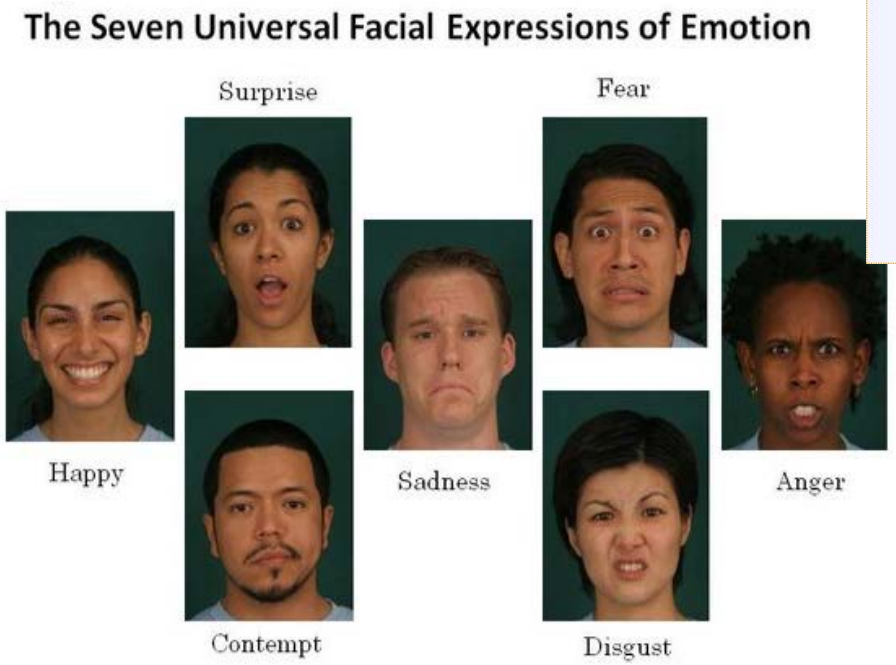
Basic and complex emotions help us to get along with our social environment. In early societies vertical social structures were dominant. Emotions like rage, fear or sadness helped to build up and maintain the hierarchy.

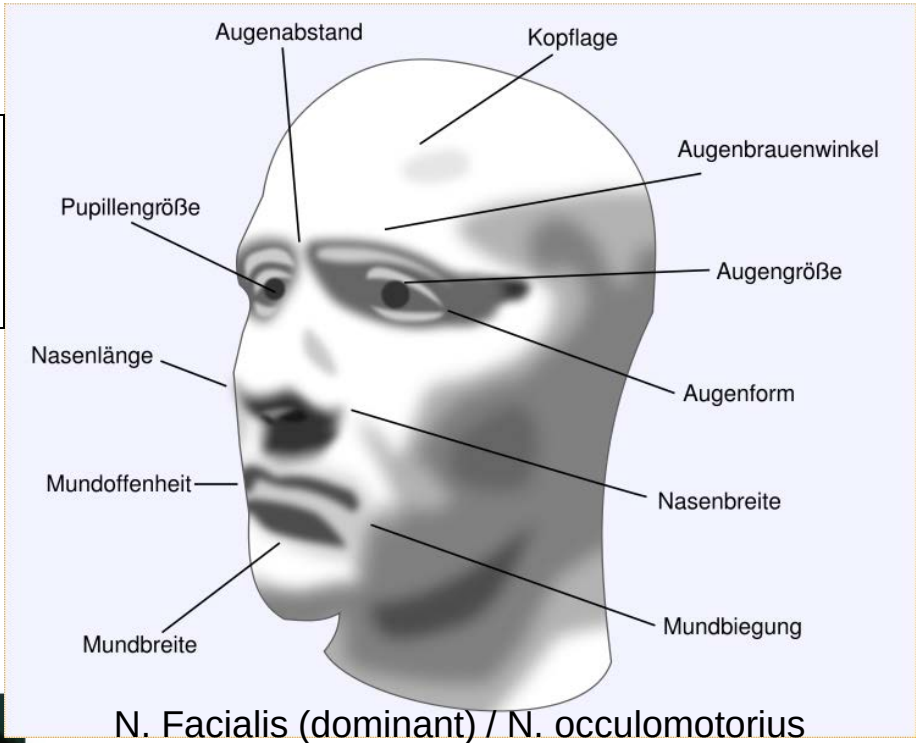
The non-verbal communication of emotional states can be found in all communities of higher primates – the innate expression and assessment of facial expressions is thus important in regulating social behaviour of the individual

Emotions

Communication of emotion:

Facial expressions





N. Facialis (dominant) / N. occulomotorius

The seven universal facial expressions of emotion are innate and valid across all cultures.

They are not subject to the cross-race-effect.

Emotions

Even when the faces are reduced to simple shapes we are able to recognise emotional information – as long as a basic emotion is displayed.

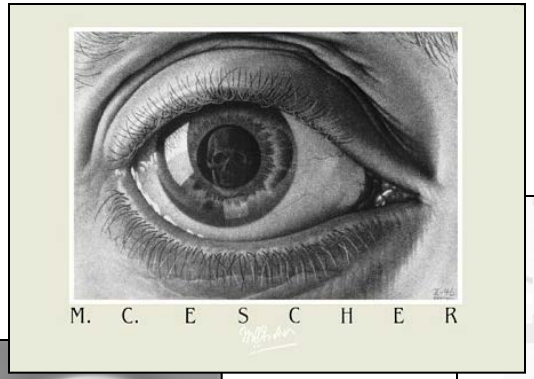
For the expression of complex emotional states, we suffer from a cross-race-effect. For Europeans the assessment of complex facial expressions is hindered for Asian or African faces (and vice versa).

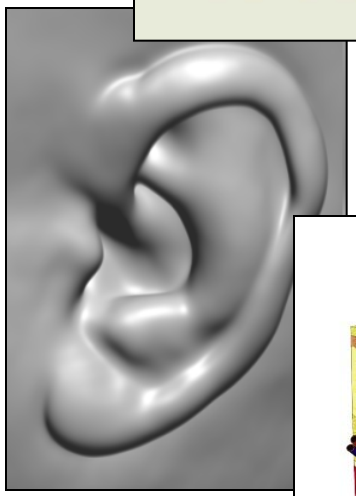
EMOTION ASSESSMNT

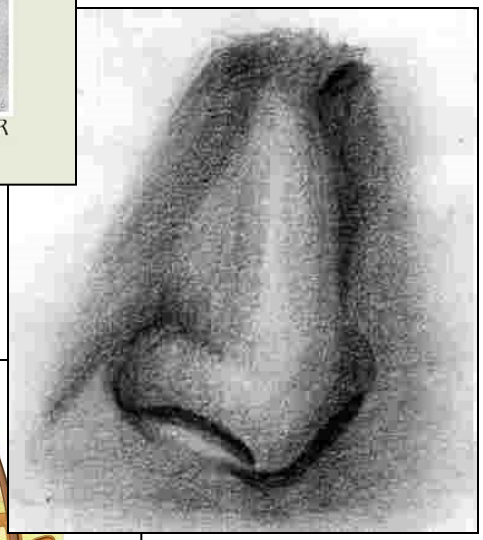
Involved Brain areas

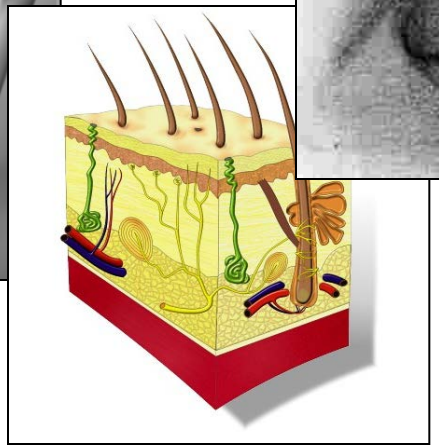
Emotion Assessment

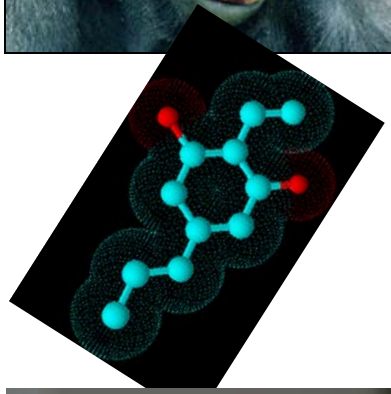
Sensor side



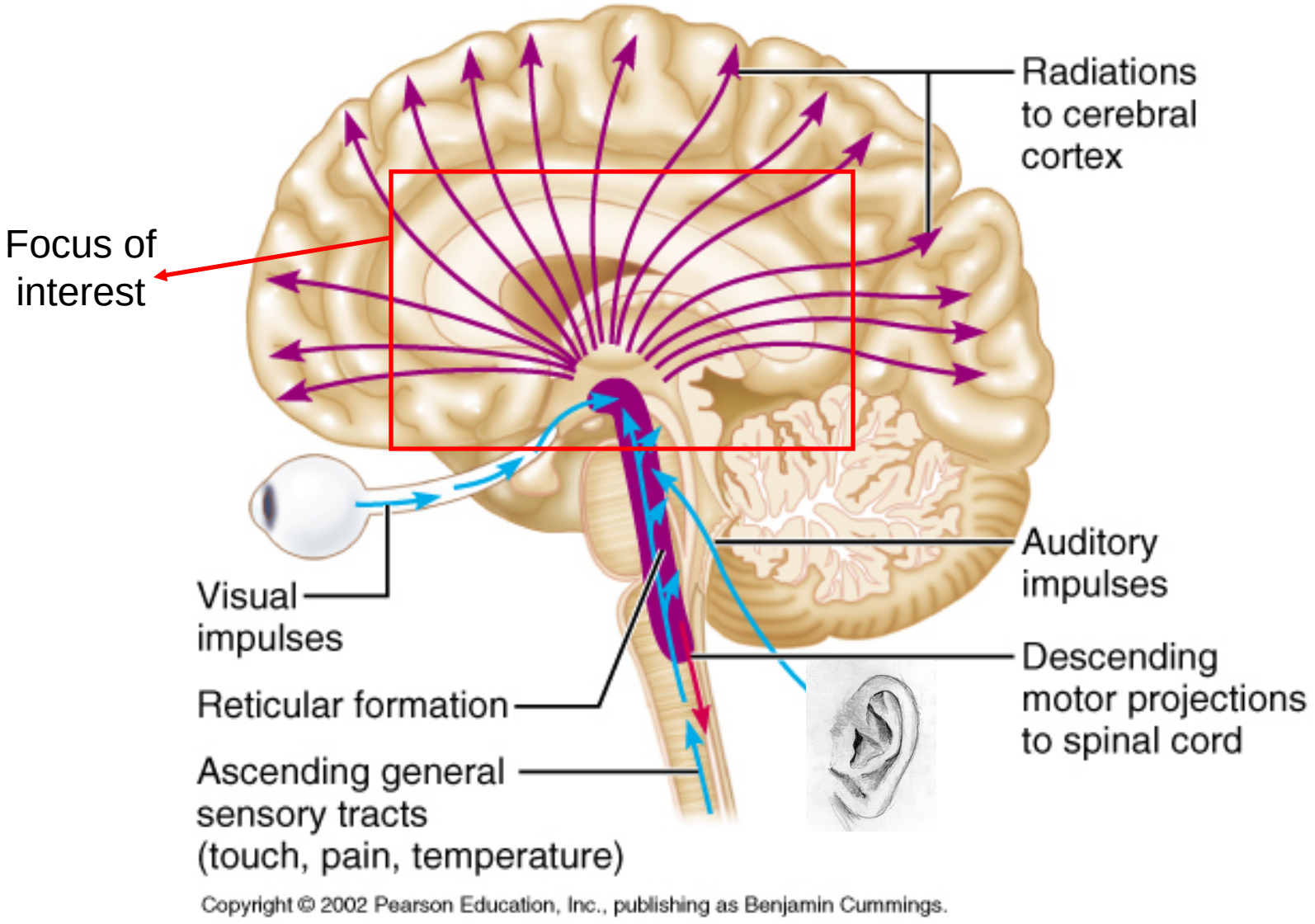






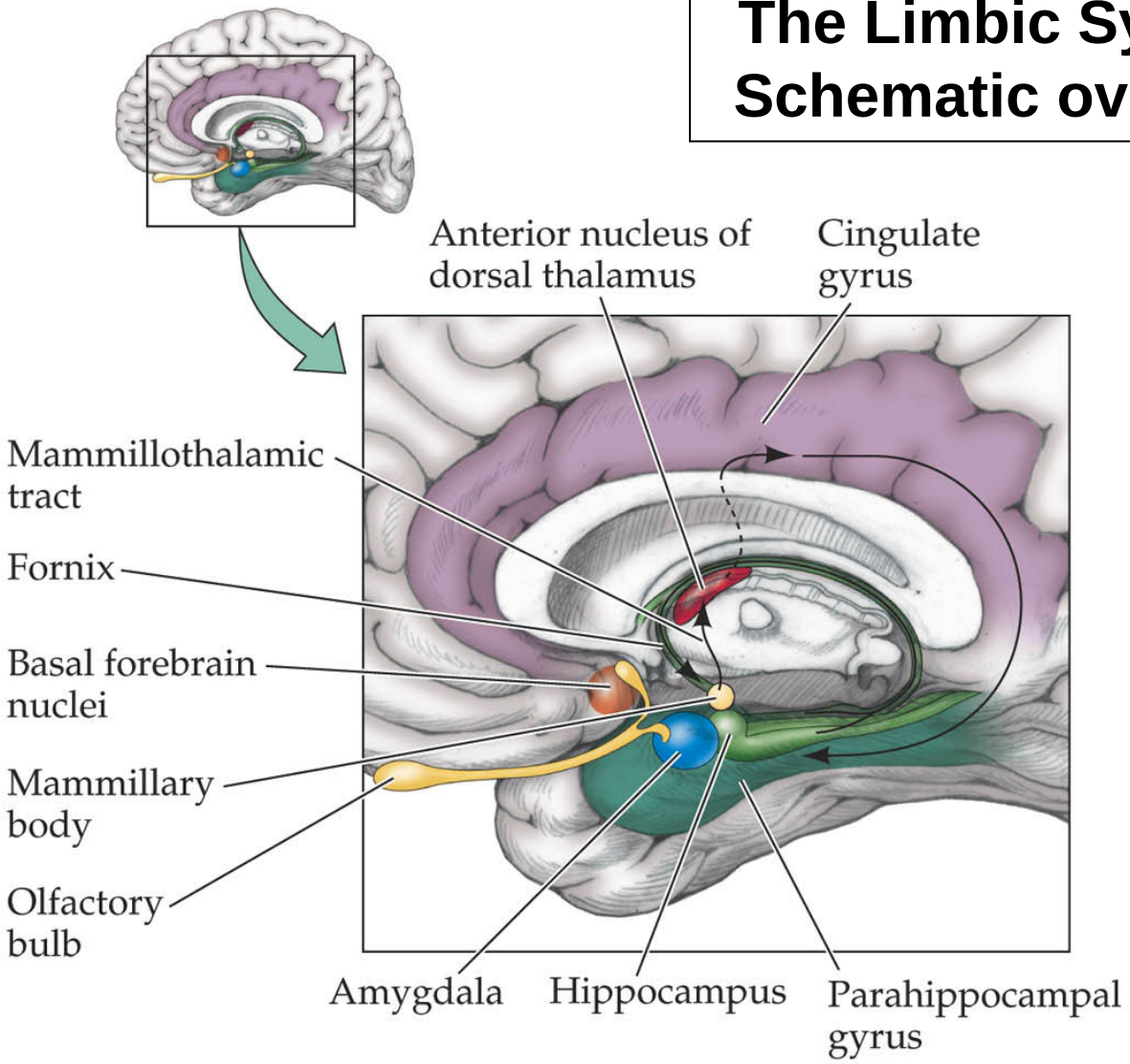


Emotion Assessment



Emotion Assessment

The Limbic System: Schematic overview



BIOLOGICAL PSYCHOLOGY, Fourth Edition, Figure 15.10

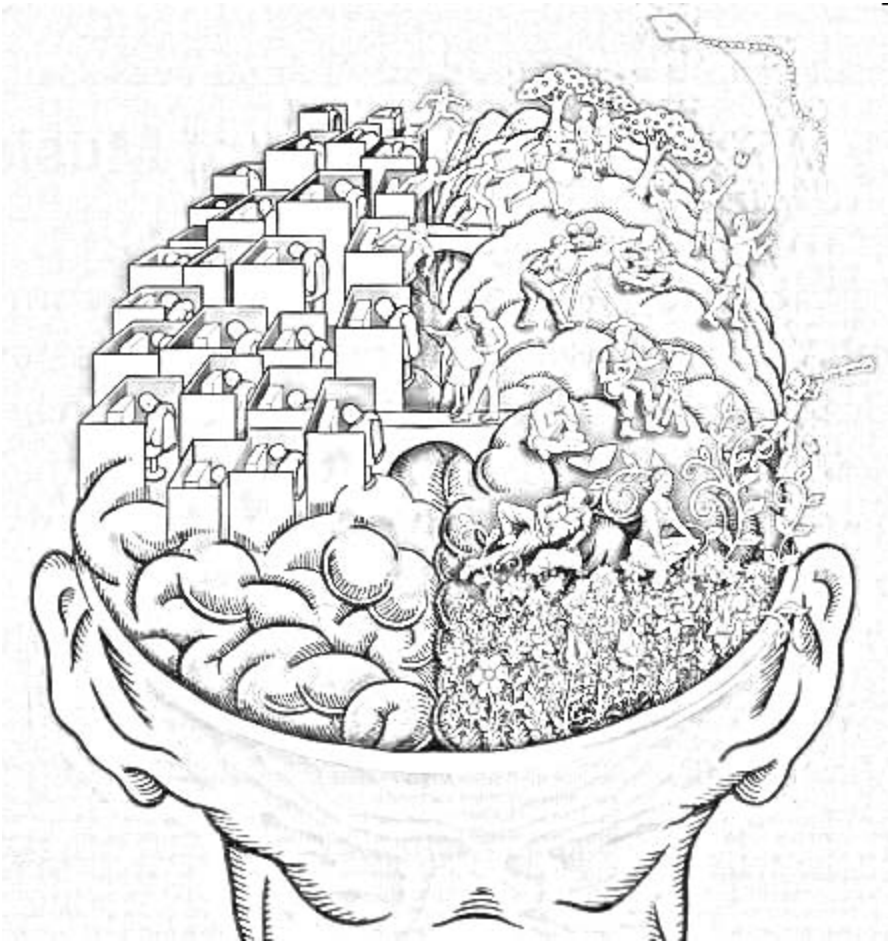
Emotion Assessment

Oldest areas of telencephalon, bordering diencephalon.

Direct connections with olfactory and taste systems, hypothalamus (visceral & emotional).

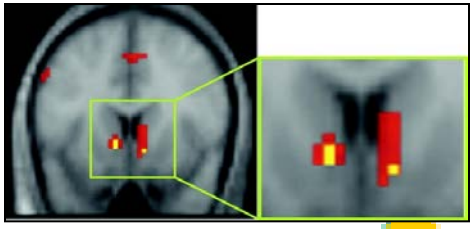
Transition from subcortex (e.g. amygdala) to 3-4 layered cortex (e.g. hippocampus) to 6-layered neocortex.

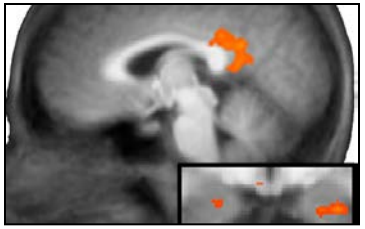
Interconnections-"Papez Circuit“, ”Mamillothalamic Tract”



Emotion Assessment

Nucleus accumbens
Posterior cingulate cortex
(ventral striatum)



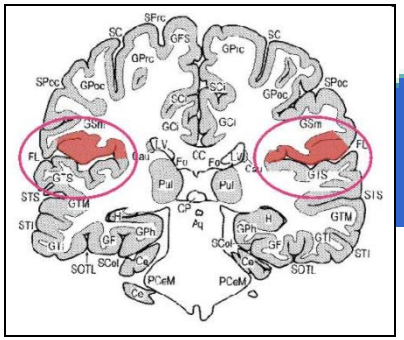


JOY

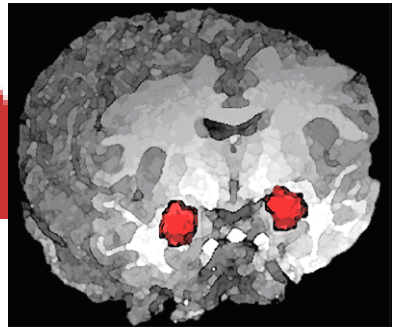
DISGUST

FEAR

Insula cortex



Amygdala



JOY:

- The **nucleus accumbens** is the engine of the reward response. The pathway activates also pain relief through the release of both opioids, produced naturally in the body, and dopamine (mimicked by amphetamine and cocaine) in the NA.

  This overturns the long-held assumption that the release of dopamine in the nucleus accumbens is associated only with positive experiences.
- Nociceptive (pain) stimuli depress mood and increase anxiety, irritability
- Antinociceptive (pain relief, analgesic) mechanisms elevate mood and decrease anxiety, irritability

JOY:

- The **posterior cingulate cortex** is a nexus in the brain strongly connected to structures responsible for decision making and to structures responsible for motivation and basic emotions.
- Compares costs and benefit for different options in the actual environmet. The PCC associates motivation with the possible outcome of an action.
- After the action the PCC is active again, comparing the actual outcome to the predicted reward.
  → Reward-prediction-error
- Damage results in spatial neglect in the visual field, hypothesized to origin from a loss of motivational significance

FEAR:

- The efferent projections to the **Amygdala** are high pre-processed for the most part (exception: olfactory path). Recent studies demonstrate direct connections from early processing stages to the amygdala.
- Comprises 13 subnuclei, grouped in 2 functional units: central amygdala (CA) and basolateral amygdala (BLA) (basal, lateral and accessory basal nuclei).
- Although the amygdala is a evolutionary old structure, the BLA has undergone comparatively recent expansion. The BLA has widespread connections to polysensory structures and planning areas, while CA has a strict striatal connectivity, serving phylogenetically simpler
- BLA is responsible for the processing of aversive stimuli and the generation of fear-reaction-patterns. The BLA plays an important role in classical conditioning (Pavlovian learning) as a association site for conditioned and unconditioned strimuli. BLA can be seen as the controler of the CA.
- In turn the CA acts as a controller of the brainstem

DISGUST

DISGUST:

- The **insula cortex** (IC) is a cortical structure within the lateral sulcus. Anatomically the IC is divided into an anterior and posterior part, which both contain multiple receptive fields.
- Main function of the IC is bodily self monitoring and the maintainance of the homeostasis: desires/needs
- The IC reacts to unpleaseant olfactory stimuli and to visual stimuli of decay and mutilation.
- The IC is also a mirror neuron system for facial expressions of disgust (see facial processing)
- A. Damasio proposed the IC to map visceral states evoked by emotions and to give rise to subjective and conscious emotional events (feelings): interpretation of body states

Emotion Assessment

AGGRESSION:

The government of aggression in animal is subject to a number of interacting brain areas and to multiple neuromodulating substances.

In all animal aggression is eclict by an increased activity of

- Medial preoptic area
- Lateral septum
- Anterior and ventromedial hypothalamus
- Periaquaeductal grey

- medial amygdala
- bed nucleus of stria terminalis

In humans the prefrontal cortex provides inhibitory projections to hypothalamus and amygdala that might promote aggession.

Emotion Assessment

AGGRESSION:

Lesions of the hippothalamus or of the amygdala (e.g. due to electrolytic treatment in the 19th century) result in reduced aggession.

The therapeutical lesion of those brain areas affected the general arousal level.

In actual herapies selective serotonine-reuptake inhi-bitors in the PFC reduce the overall aggession level.

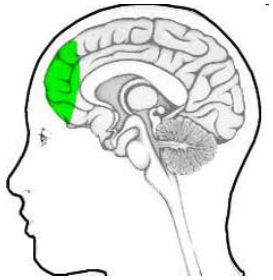
Intranasal administration of oxytocin can also reduce aggession due to a reduction in amygdala activity.

Modulatory effects on aggressive behaviour are governed by a number of chemical messengers in the brain:

Dopamine (arousal, anticipation), GABA & GAD (septal forebrain), Nordadrenaline (hyperarousal, dose specific), Nitric oxide (break), Monoamine Oxidase, Steroid hormons (e.g. Sexual hormones)

Emotion Assessment

The **Prefrontal Cortex**: planing and motivating



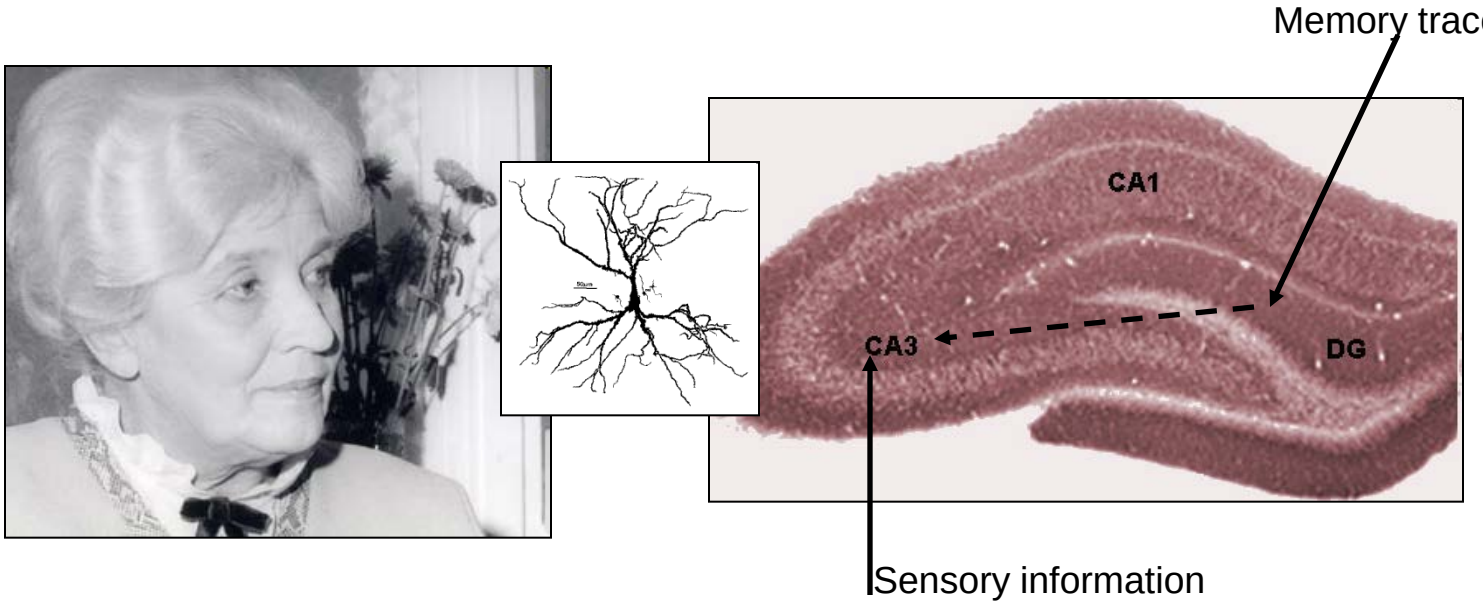
The PFC is the anterior part of the frontal lobe and comprises 9 Brodman areas. We distinguish between a dorsolateral, orbito-frontal and a frontopolar region (dorsolateral can be segmented in three more acute areas).

PFC is responsible for the conscious processing of rewards and punishes and the long-term planning of emotions, motives and actions.
Weak lateralization of emotions in right frontal cortex.

Damage to the PFC results in schizophrenia and depression up to a level of an loss of empathy or an inability to interpret reality.

Emotion Assessment

The **Hippocampus**: Novelty detection



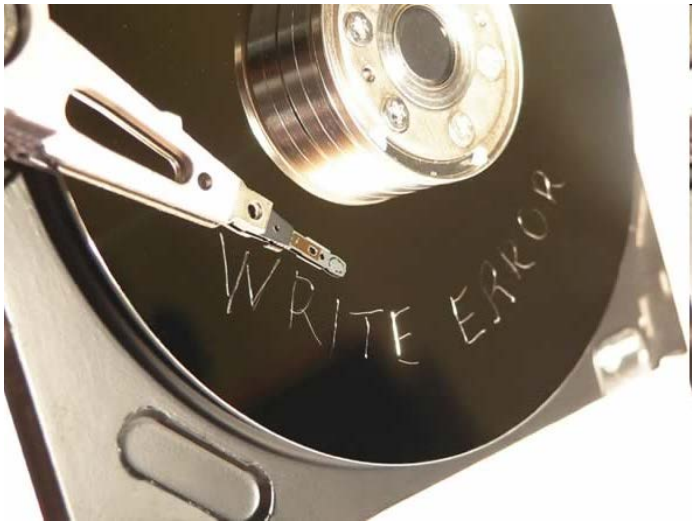
The hippocampus acts as a novelty detector in the brain, comparing incoming sensory information to already existing memory traces.

Strong influence to complex-emotion related behaviour due to a lack of information like curiosity in explorative behaviour.

Emotion Assessment

The Hippocampus: Memory and Emotions

- The ecliction of emotions is highly context-dependend. Most stimuli are able to give rise to a number of different emotions.
- This calls for a strong interaction of memory and emotions.
- Responsible to the creation and consolidation of associative reactions of fear
- Interaction with the amygdala for the evaluation of overall context
- Together with amygdala control of incoming sensory information by attentional guidance → LTP



Emotion Assessment

Association

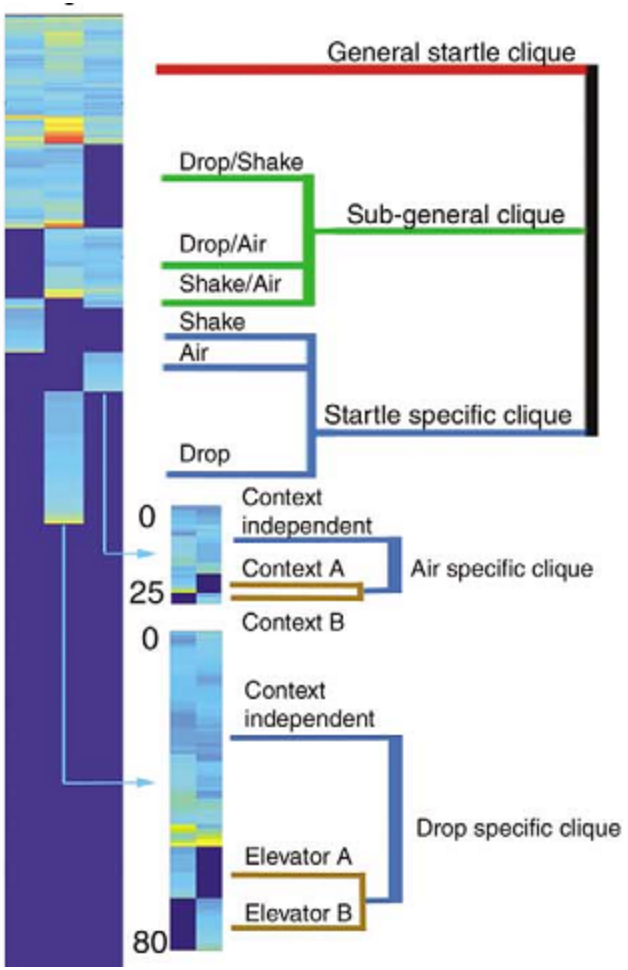
Association is the process of linking existing memory traces to incoming sensory information.

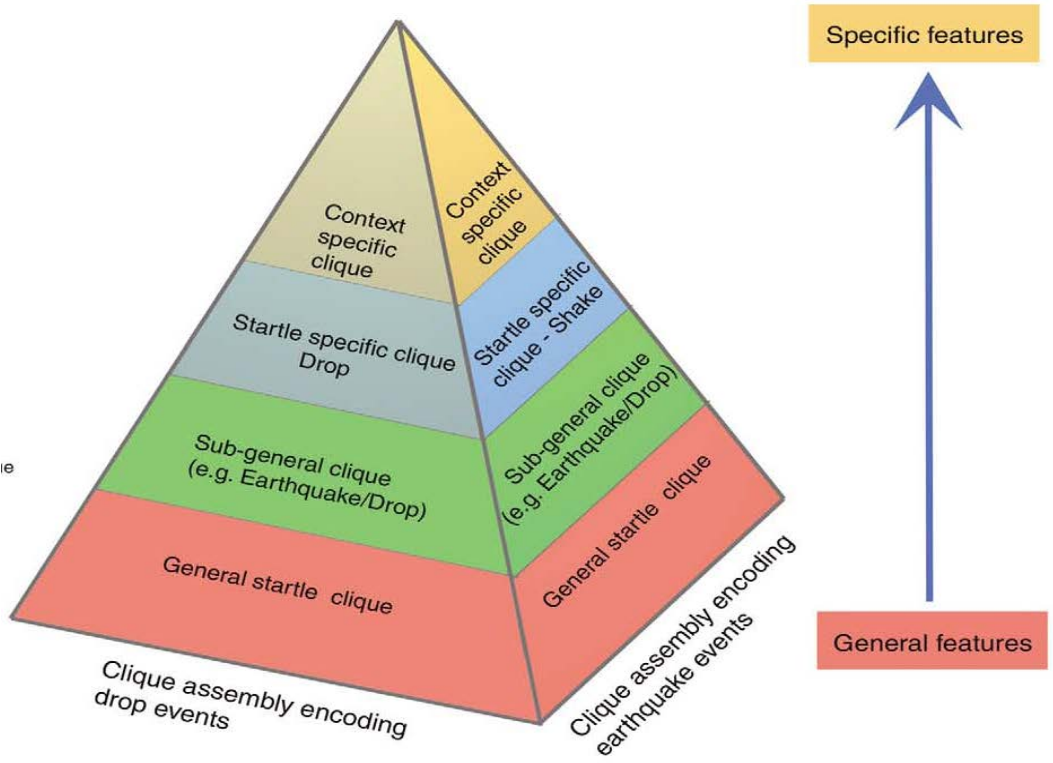
Association is essential for classifying sensory information and activation of behavioural circuits

Association is linked to novelty detection mechanisms and working memory. The link to brain areas of emotion-processing can also influence mechanisms of habituation (and attention)

Emotion

Association

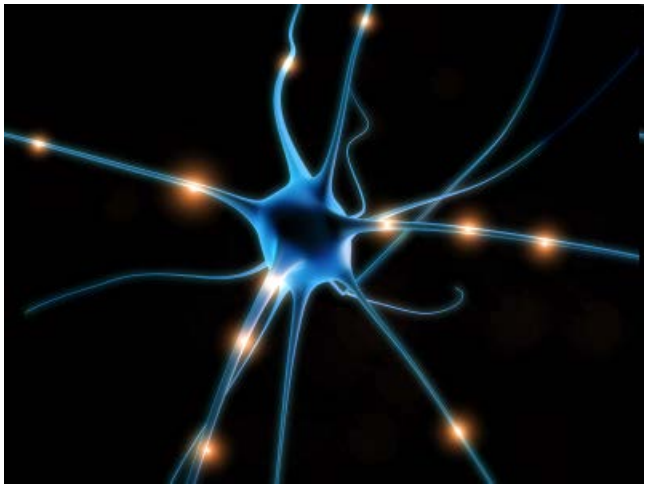




Organizing principles of real-time memory encoding: L. Lin 2006

Emotion Assessment

- Facial processing in the brain / the mirror neuron
- Erkennung von ängstlichen Gesichtern
- • Amygdala spielt auch eine Rolle beim Erkennen von
- ängstlichen Gesichtern:
- – Frau mit Amygdala-Schaden erkennt alle Gesichtsausdrücke
- – Ausnahme: ängstliche Gesichter
- • Studie von Whalen et al. (1998)
- – Präsentation von Gesichtern, so dass Vpn Gesichtsausdruck
- nicht berichten konnten
- – Bei ängstlichen Gesichtern: Amygdala-Aktivität
- • Amygdala als frühes Warnsystem:
- nimmt potentielle Gefahren wahr, bevor wir uns
- ihrer bewusst sind

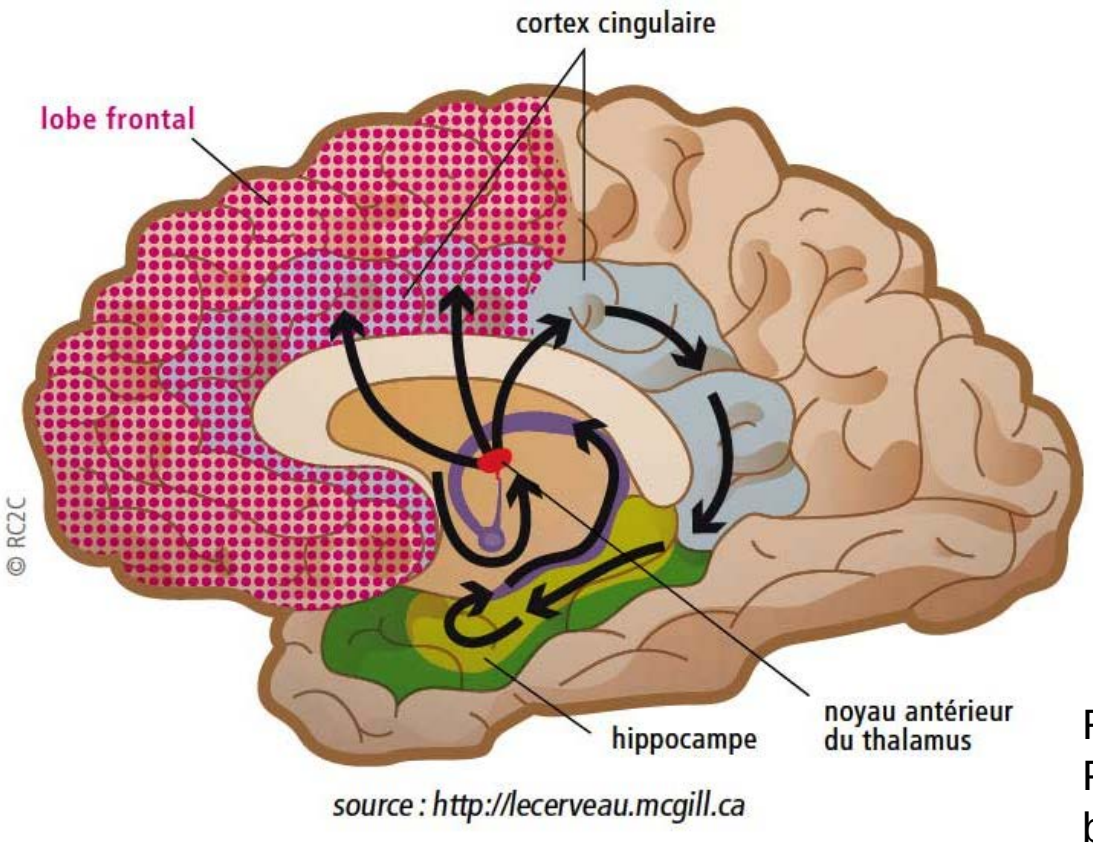


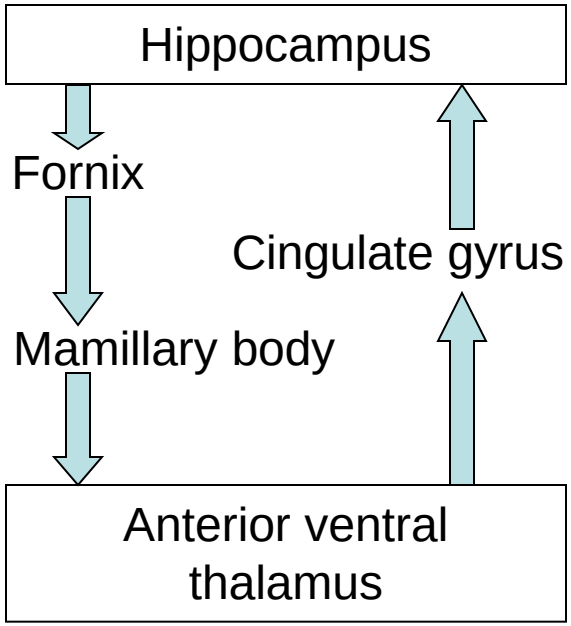
Behavioural relevance

Linking different messenger systems

Behavioural relevance

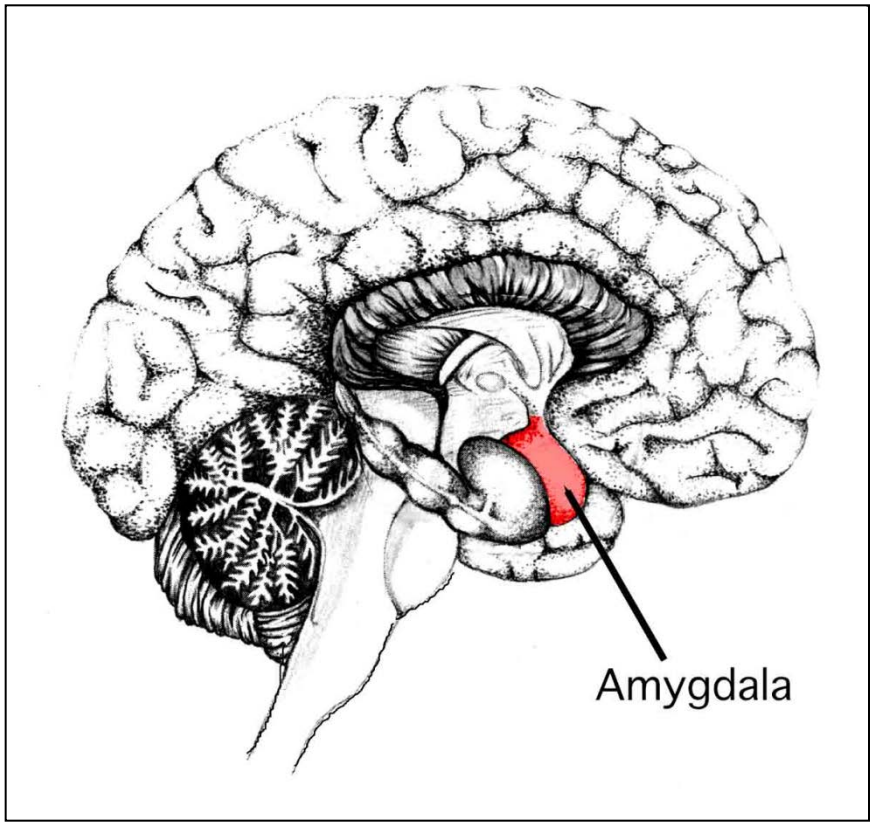
Papez‘ circuit – the first approach to the explanation of emotions





Recent studies suggest that the Papez circuit does not govern rage, but serves as a memory store for recent traces for the conversion from primary to secondary memory.

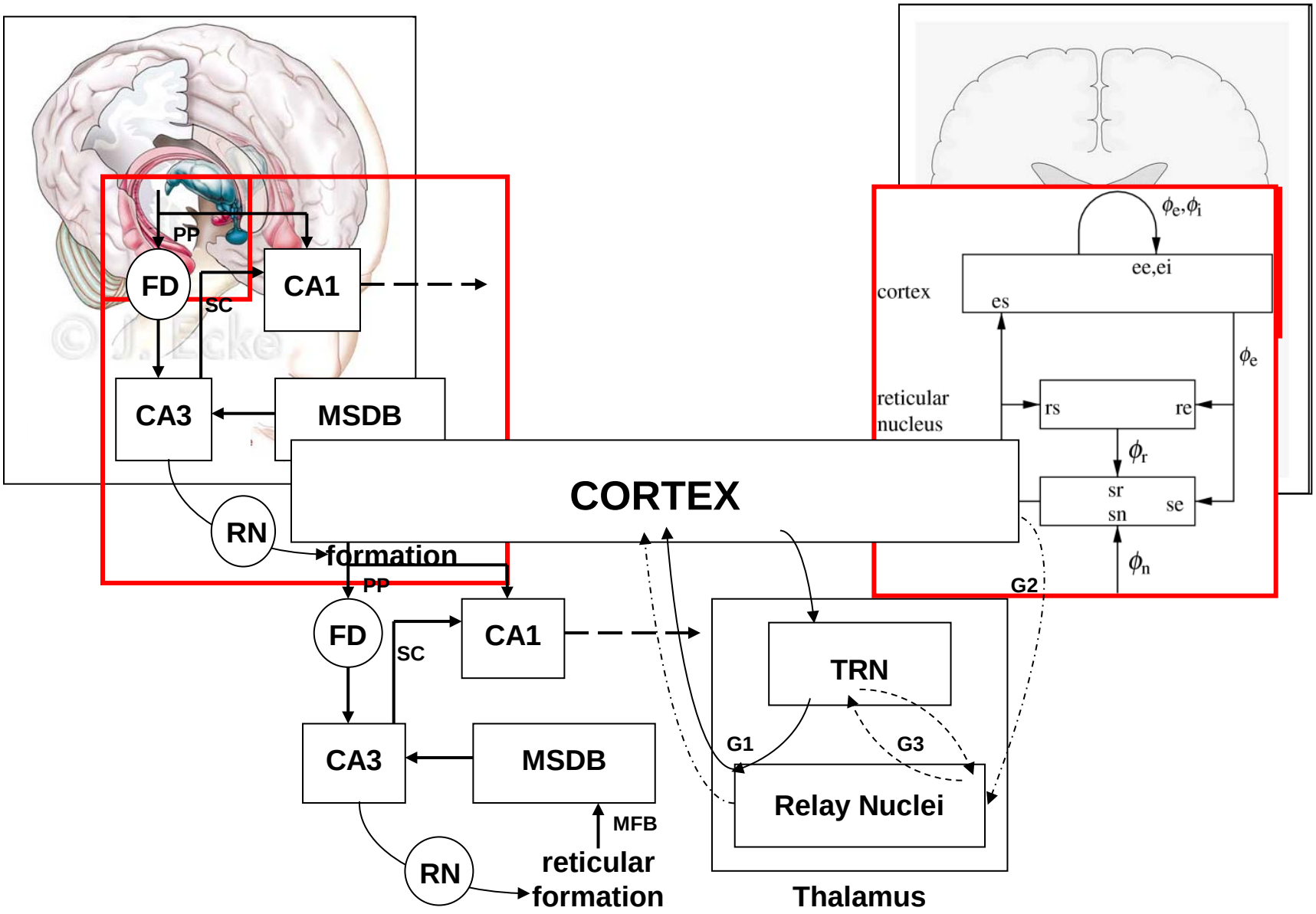
Behavioural relevance



Verarbeitung von sensorischer Information:

- **emotionale Bewertung der Information**
- **Auslösen von vegetativen Reaktionen**
- **Angstreaktionen**

Bindung von Aufmerksamkeit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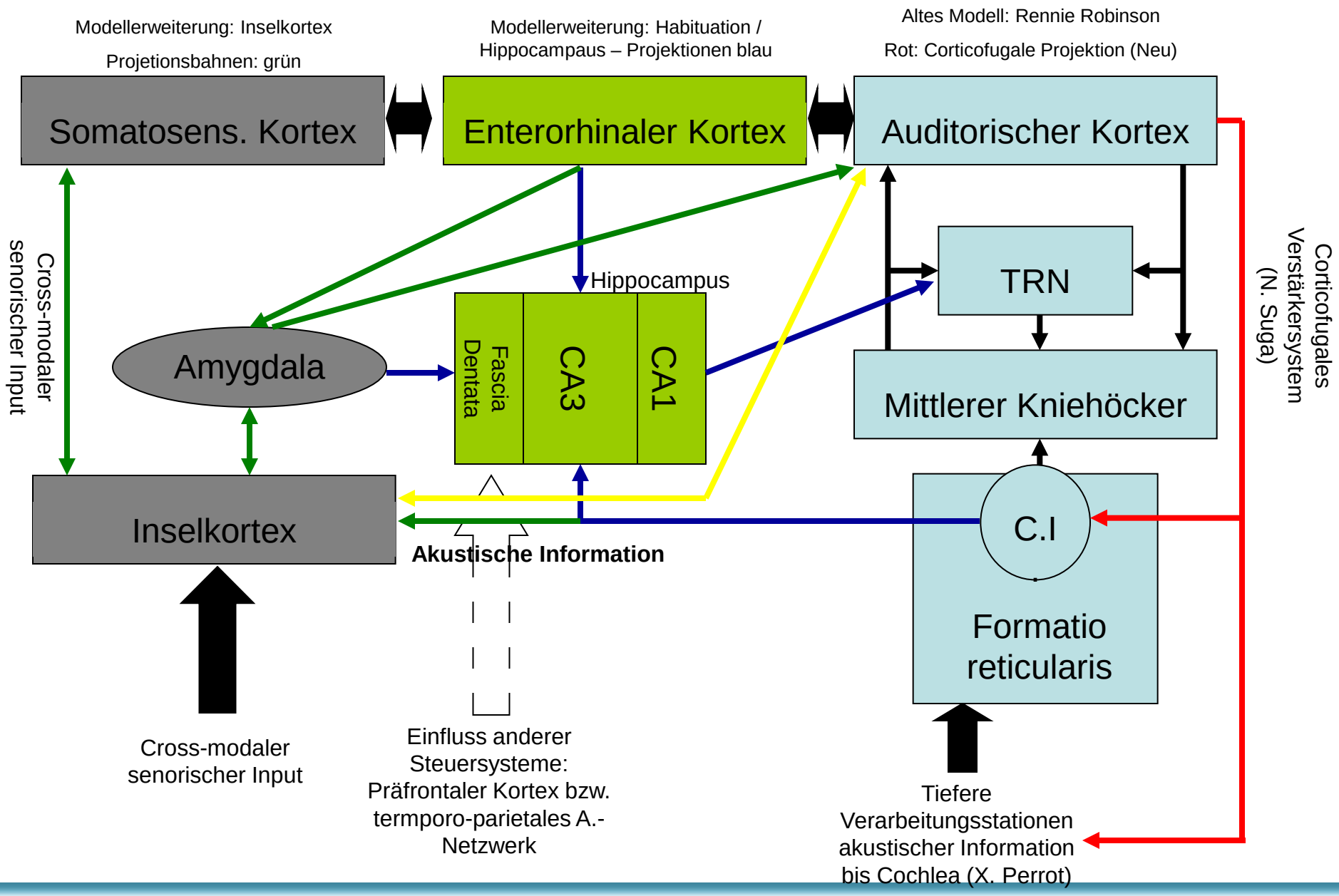
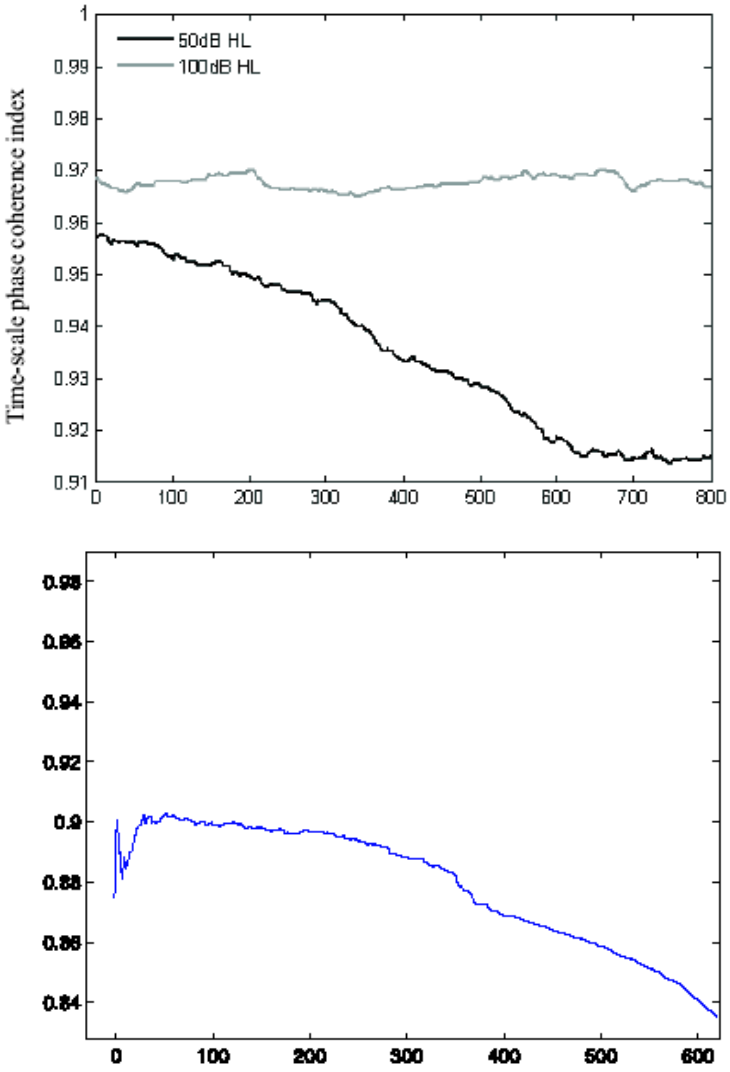
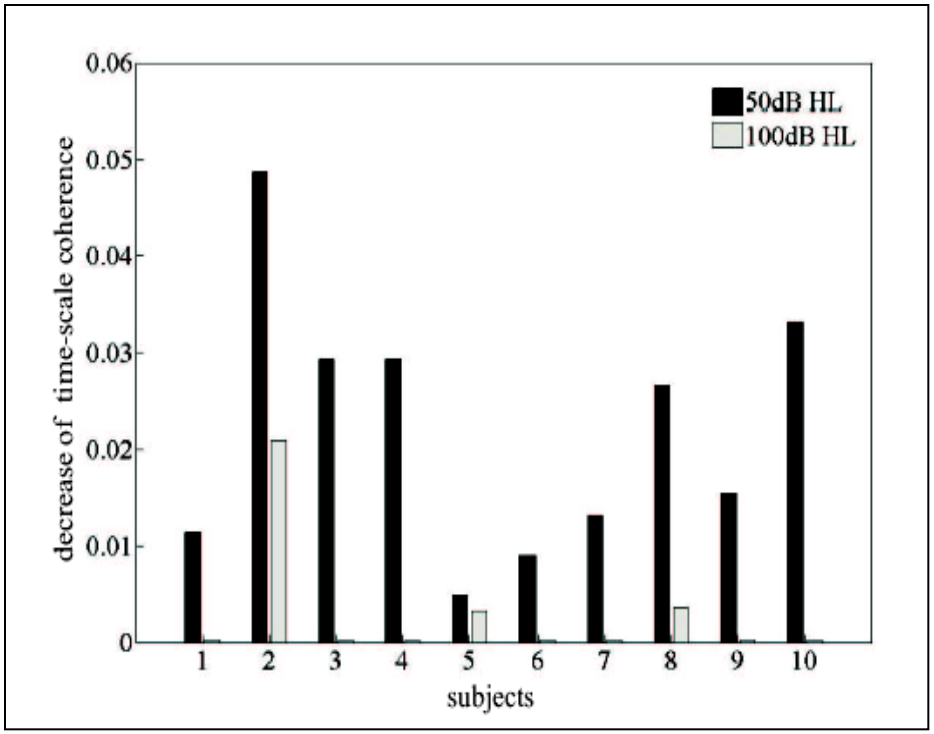
CA1
CA3
MSDB
MFB
RN
reticular
formation
TRN
Relay Nuclei
G1
G3
Thalamus
cortex
es
ee,ei
ϕ_e,ϕ_i
ϕ_e
reticular
nucleus
rs
re
ϕ_r
sr
sn
se
ϕ_n
G2


Modellerweiterung: Inselkortex
Projetionsbahnen: grün
Modellerweiterung: Habituation / Hippocampaus – Projektionen blau
Altes Modell: Rennie Robinson
Rot: Corticofugale Projektion (Neu)
Somatosens. Kortex
Enterorhinaler Kortex
Auditorischer Kortex
Cross-modaler senorischer Input
Hippocampus
Fascia Dentata
CA3
CA1
TRN
Amygdala
Mittlerer Kniehöcker
Corticofugales Verstärkersystem (N. Suga)
Inselkortex
C.I
Akustische Information
Formatio reticularis
Cross-modaler senorischer Input
Einfluss anderer Steuersysteme: Präfrontaler Kortex bzw. termporo-parietales A.-Netzwerk
Tiefere Verarbeitungsstationen akustischer Information bis Cochlea (X. Perrot)

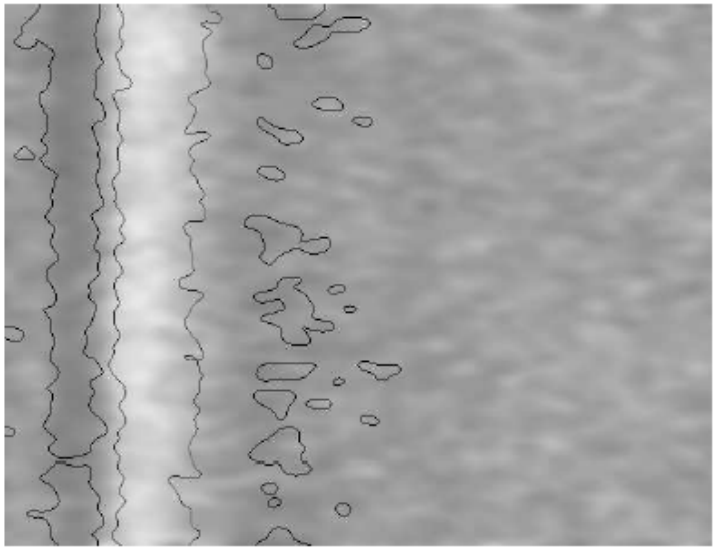
Behavioural relevance

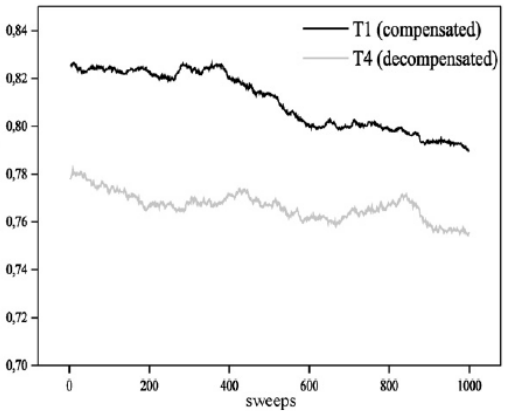


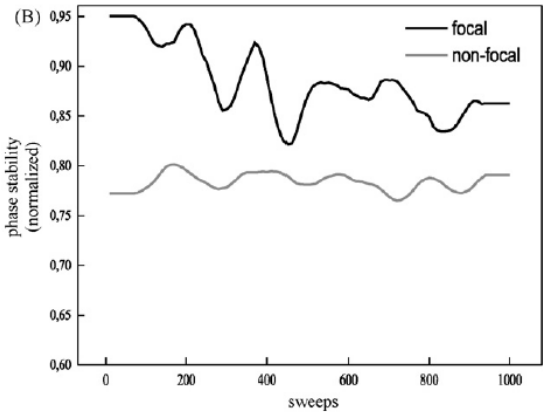


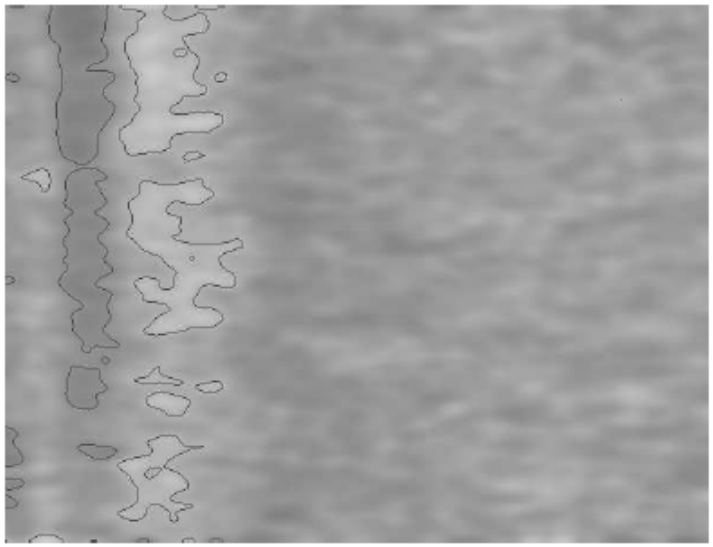
Experimental results on attentional guidance due to unpleaseant stimulation

Behavioural relevance





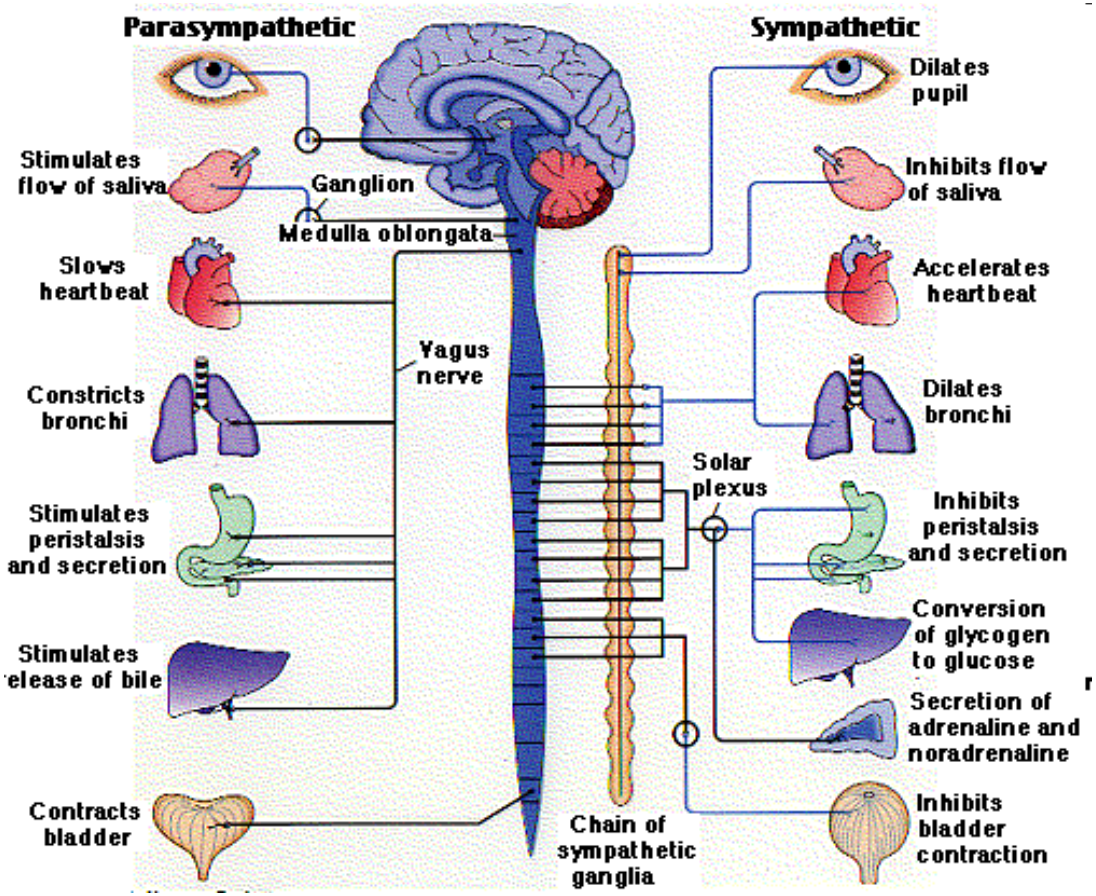




Experimental results on attentional guidance in tinnitus patients. We hypthesize attentional binding due to the aversive acoustical sensation.

Behavioural relevance

Central amygdala: hypothalamus and the medulla oblongata,



Behavioural relevance

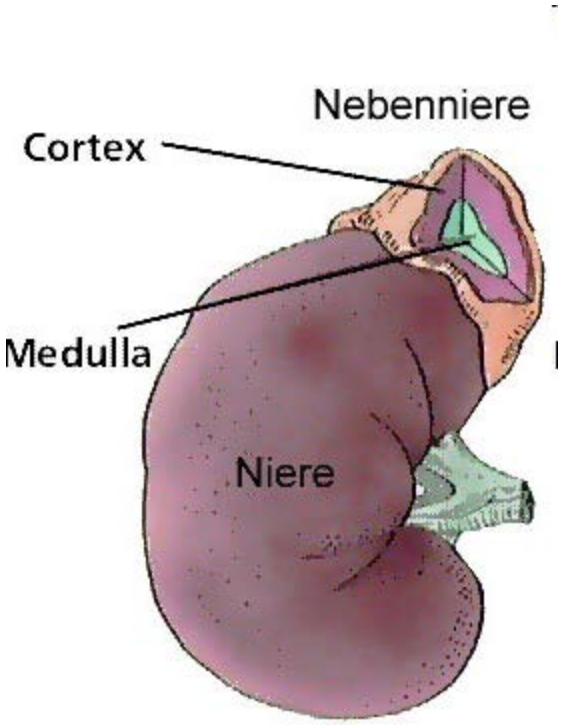
Central amygdala: suprarhenal gland

By the activation of the sympathic nervous system, the limbic system also influences the level of hormones in the bodily blood-stream.

Stress-reaction leads to increased secretion of corticosteroides (via hypothalamus, hypo-physis and suprarhenal gland).

Secretion of adrenaline and noradrenaline increases the sympathic effect → next slide

Feedback loop: The increased levels of nor-adrenaline and cortisol also increase the amygdala activity → Fear reaction to long-term increase of (nor-)adrenaline levels.



Behavioural relevance

TAB. 7 ▶ Wirkungen von Adrenalin

Herz	positiv chronotrop, inotrop, dromotrop (β_1)
Blutdruck	systolisch ↑ durch Vasokonstriktion (α_1)
	diastolisch ↓ durch Vasodilatation der Muskelgefäße (β_2)
Leber, Skelettmuskulatur	Glykogenolyse ↑, Glukoneogenese ↑ (β_2)
Lunge	Bronchodilatation (β_2)
Fettgewebe	Lipolyse ↑ (β_1)
Magen-Darm-Trakt	Tonus glatter Muskulatur ↓ (α_2)
weitere Effekte:	Mydriasis
	Schweißsekretion ↑
	Aufrichten der Haare
	Steigerung von Blutzucker, O_2-Verbrauch, Grundumsatz und Körpertemperatur
	verstärkte ACTH-Sekretion des Hypophysenvorderlappens und Anstieg des Cortisol

TAB. 8 ▶ Wirkungen von Noradrenalin

Vasokonstriktion (α_1)	Blutdruck ↑ (systolisch und diastolisch)
Herz	negativ chronotrop
	reflektorisches Absinken der Herzfrequenz durch Blutdruck ↑
Bronchokonstriktion (α_1)	
mentale Stressanpassung	

Behavioural relevance