KING'S College LONDON

INSTITUTE OF PSYCHIATRY,
PSYCHOLOGY & NEUROSCIENCE

Module:
Biological foundations of mental health

Week 5:
Reward, emotion and action

Dr Frank Hirth

Topic 2
The structure and function of the Basal Ganglia

Part 5 of 5

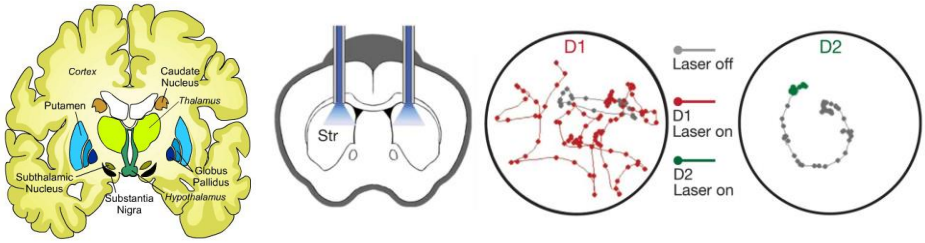
Voluntariness and Free Will (1)

The basal ganglia – voluntariness or free will

Figure 8: Is free will an illusion?

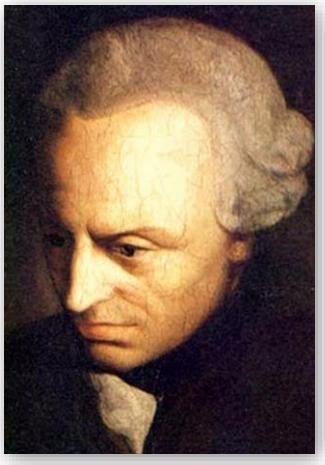
Voluntariness and Free Will (2)

Is free will expressed by our freedom to do what we want?



Remember: optogenetic activation of the indirect pathway suppresses actions (right arena).
Does that mean the mouse is deprived of her freedom to do what she wants?

Voluntariness and Free Will (3)



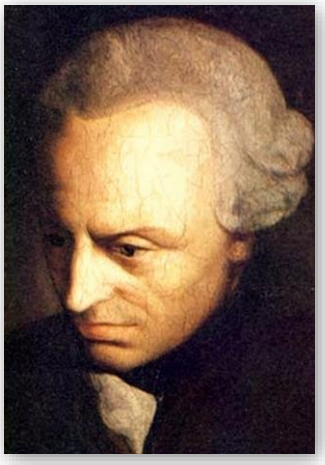
The philosopher Kant (1724-1805) said:

A person acts freely if he does of his own accord what must be done.

Think of people with basal ganglia dysfunctions: they are impaired in their actions.

In a way they are deprived in expressing their free will.

Voluntariness and Free Will (4)



According to Kant, we are on the one hand determined by natural law and on the other hand free because of our capacity to obey moral law.

Think of people with basal ganglia dysfunctions who are impaired in their judgements!

Voluntariness and Free Will (5)

So what is free will?

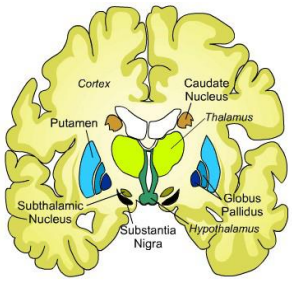
Has it anything to do with the basal ganglia?

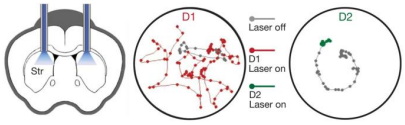
> "The only output of the nervous system is the motor system, whether in cognition or action."
> (Sten Grillner)

Evolution of the Basal Ganglia (1)

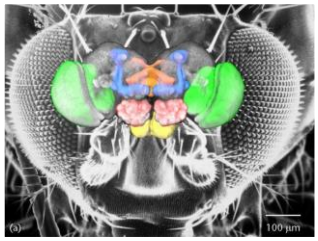
Central Brain Regions Involved in Action Selection

Vertebrate Basal Ganglia





Arthropod Central Complex



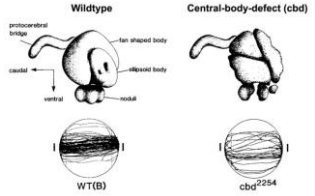
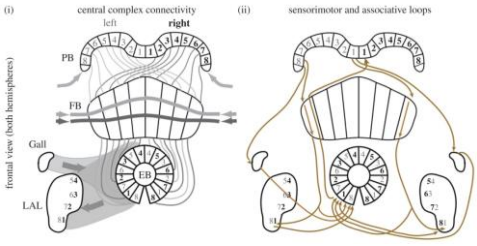


Figure 9: Anthropod central complex

Evolution of the Basal Ganglia (2)

Functional Anatomy of the CX and BG

Insect brain (*Drosophila*)



Mammalian / primate brain

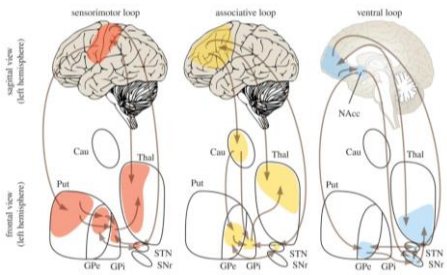


Figure 10: Functional anatomy of the Drosophila central complex

Spatially organised parallel-projecting loops integrate and convey sensorimotor representations that select and maintain behavioural activity.

Evolution of the Basal Ganglia (3)

Behavioral manifestations regulated by neuronal activity of vertebrate basal ganglia and insect central complex.

Basal Ganglia *Striatum, Globus Pallidus* *Subthalamic nucleus,* *Substantia nigra*	**Central Complex** *Protocerebral Bridge,* *Fan-Shaped Body, Ellipsoid Body,* *Lateral Accessory Lobe*
Postural muscle tone	
Coordinated locomotion	Coordinated locomotion
Goal-directed movement	Goal-directed movement
Saccadic eye movement	
Visual orientation and space integration	Visual orientation and space integration
Sleep	Sleep
Arousal	Arousal
Attention	Attention
	Courtship behaviour
Sensorimotor learning	Place memory
Habit learning	
Reward-seeking behavior	Reward-seeking behavior
Emotional expression	

Shared "Action Selections"

Evolution of the Basal Ganglia (4)

Basal Ganglia and Central Complex Dysfunction
Homologous Pathological Manifestations

Motor Abnormalities

Impaired Memory Formation

Attention Deficits

Affective Disorders

Sleep Disturbances

Evolution of the Basal Ganglia (5)

Corresponding Circuit Organisation of BG and CX

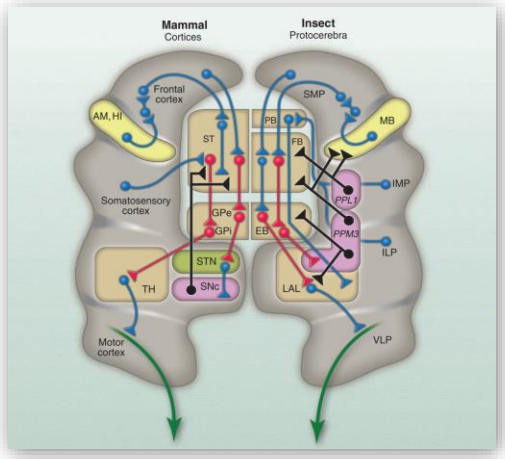


Figure 11: Deep Homology of Arthropod Central Complex and Vertebrate Basal Ganglia

Figure references

1. **Figure 1**: Source: http://tourette.org/Medical/DBS.html
2. **Figure 2**: https://commons.wikimedia.org/wiki/File%3ABasal_Ganglia_lateral.svg, by Badseed utilizing the work of Leevanjackson and John Henkel. [Public domain], via Wikimedia Commons
3. **Figure 3**: Source: http://web.stanford.edu/group/hopes/cgi-bin/hopes_test/the-hopes-brain-tutorial-text-version/#basal-ganglia
4. **Figure 4 & 10**: Fiore VG, Dolan RJ, Strausfeld NJ, Hirth F (2015). Evolutionarily conserved mechanisms for the selection and maintenance of behavioural activity. *Philos Trans R Soc Lond B Biol Sci*. Dec 19;370(1684). pii: 20150053. doi: 10.1098/rstb.2015.0053.
5. **Figure 5**: Kravitz AV, Freeze BS, Parker PR, Kay K, Thwin MT, Deisseroth K & Kreitzer AC (2010) Regulation of parkinsonian motor behaviours by optogenetic control of basal ganglia circuitry. *Nature* 466, 622-626.
6. **Figure 6**: Source: http://alzheimers.about.com/od/diagnosisofalzheimers/tp/Types-of-Dementia.htm
7. **Figure 7**: Dauer W and Przedborski S (2003). Parkinson's Disease: Mechanisms and Models. *Neuron*, Volume 39, 889–909.
8. **Figure 8**: Heisenberg M (2009). Is free will an illusion? *Nature* 459, 164-165, doi:10.1038/459164a; Published online 13 May 2009
9. **Figure 9:** Strauss, R., Heisenberg, M. (1993). A higher control center of locomotor behavior in the Drosophila brain. *J. Neurosci.* 13(5): 1852--1861.
10. **Figure 11**: Strausfeld NJ, Hirth F (2013). Deep Homology of Arthropod Central Complex and Vertebrate Basal Ganglia. *Science*, 340: 157-161, DOI: 10.1126/science.1231828