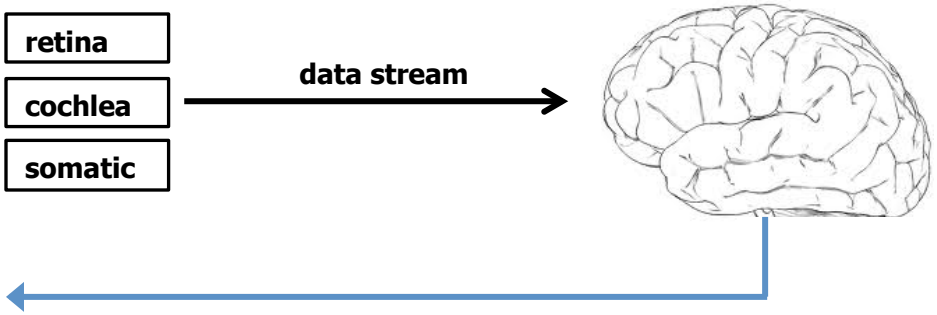
The neocortex is a memory system.



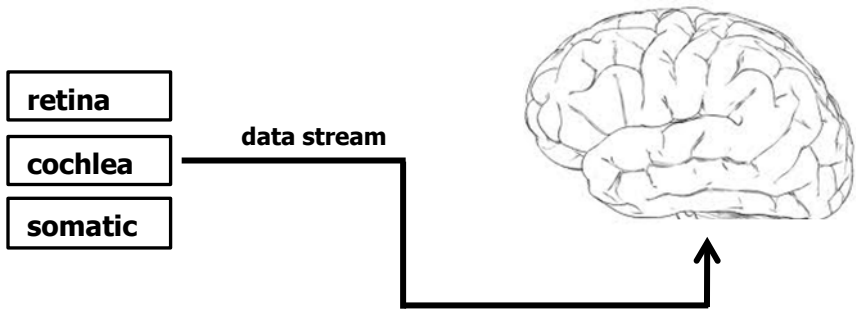
The neocortex learns a model from sensory data

- predictions
- anomalies
- actions

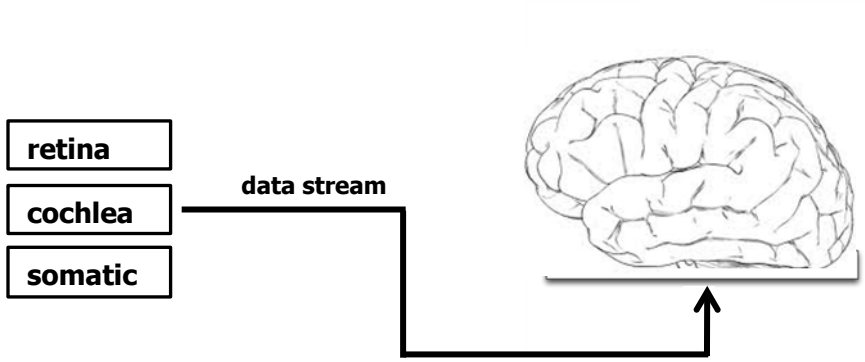
The neocortex learns a sensory-motor model of the world

Principles of Neocortical Function

1) On-line learning from streaming data



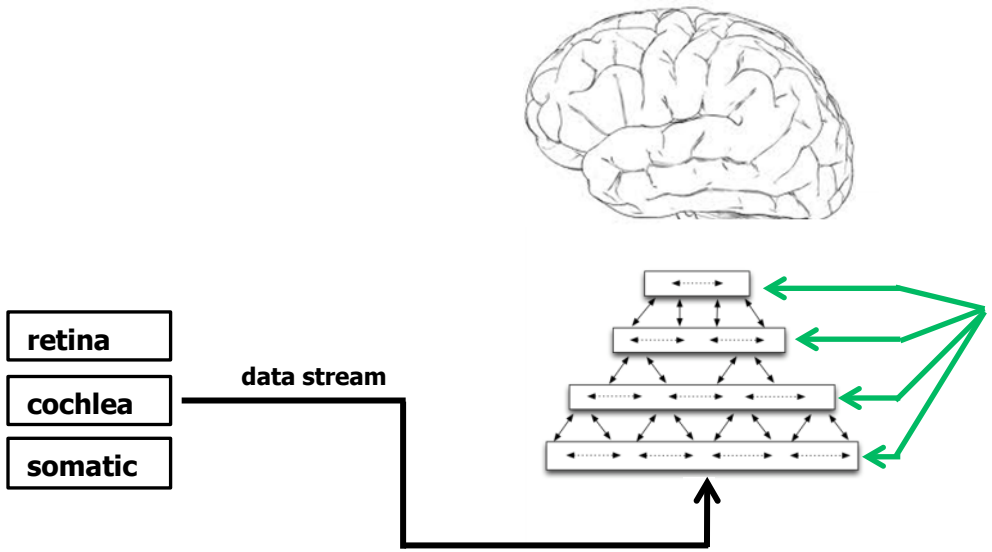
Principles of Neocortical Function



1) On-line learning from streaming data

2) Hierarchy of memory regions

Principles of Neocortical Function

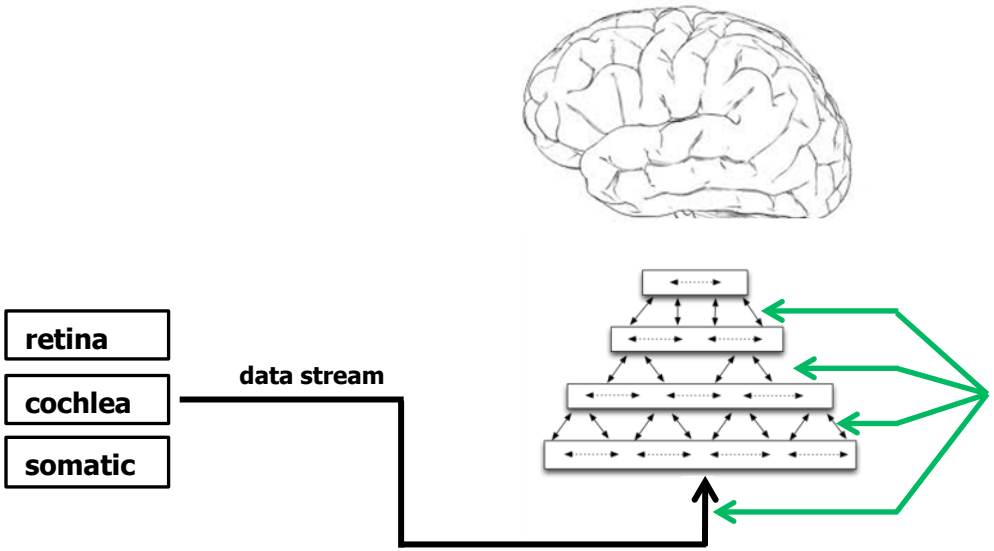


1) On-line learning from streaming data

2) Hierarchy of memory regions

3) Sequence memory
   - inference
   - motor

Principles of Neocortical Function



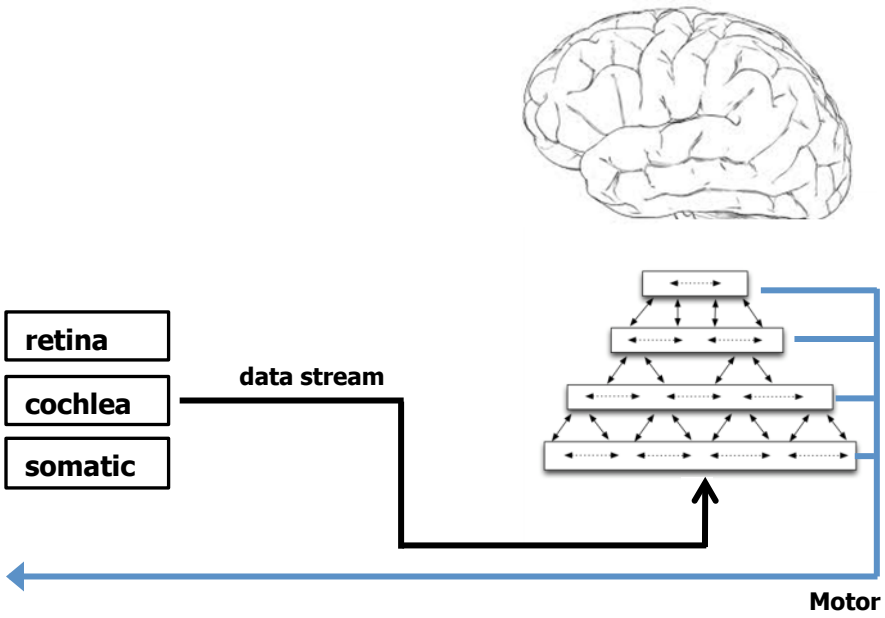
1) On-line learning from streaming data

2) Hierarchy of memory regions

3) Sequence memory

4) Sparse Distributed Representations

Principles of Neocortical Function



1) On-line learning from streaming data

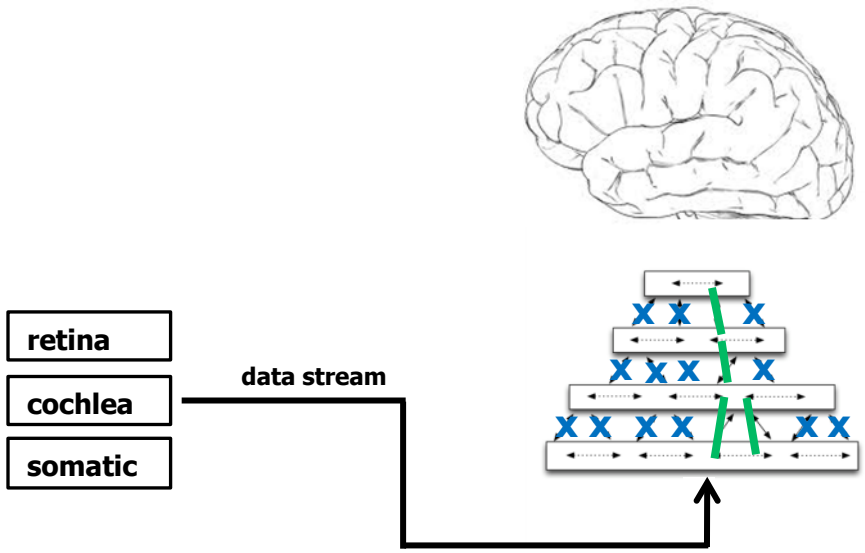
2) Hierarchy of memory regions

3) Sequence memory

4) Sparse Distributed Representations

5) All regions are sensory and motor

Principles of Neocortical Function



1) On-line learning from streaming data

2) Hierarchy of memory regions

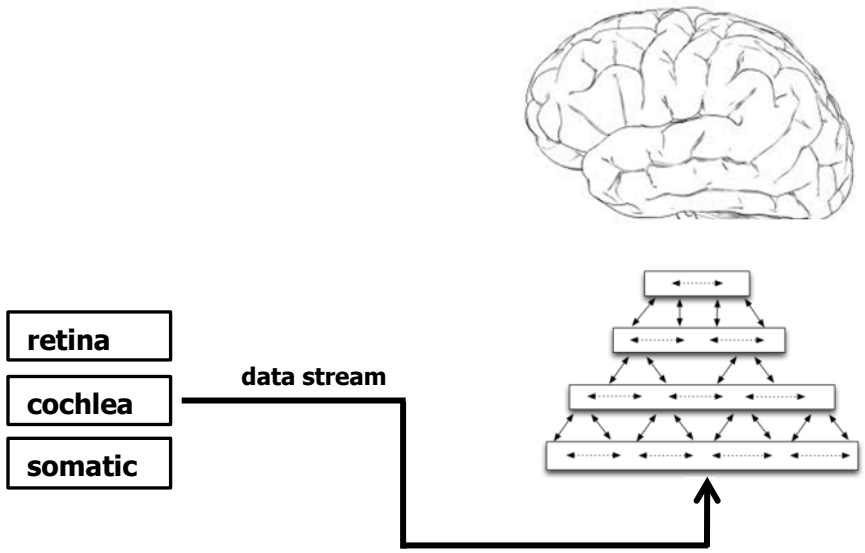
3) Sequence memory

4) Sparse Distributed Representations

5) All regions are sensory and motor

6) Attention

Principles of Neocortical Function



1) On-line learning from streaming data
2) Hierarchy of memory regions
3) Sequence memory
4) Sparse Distributed Representations
5) All regions are sensory and motor
6) Attention

These six principles are necessary and sufficient for biological and machine intelligence.

- All mammals from mouse to human have them

What is the Problem?

Sensorimotor integration
Sensory-motor contingencies
Embodied A.I.
Symbol grounding

- Most changes on our sensors are due to our own actions.

- Our model of the world is a "sensorimotor model"

- How does the cortex learn this model and act on it?
- How do we add behavior to Grok?

Attributes of Solution

Independent of sensory modality and motor modality

Should work with biological and non-biological senses

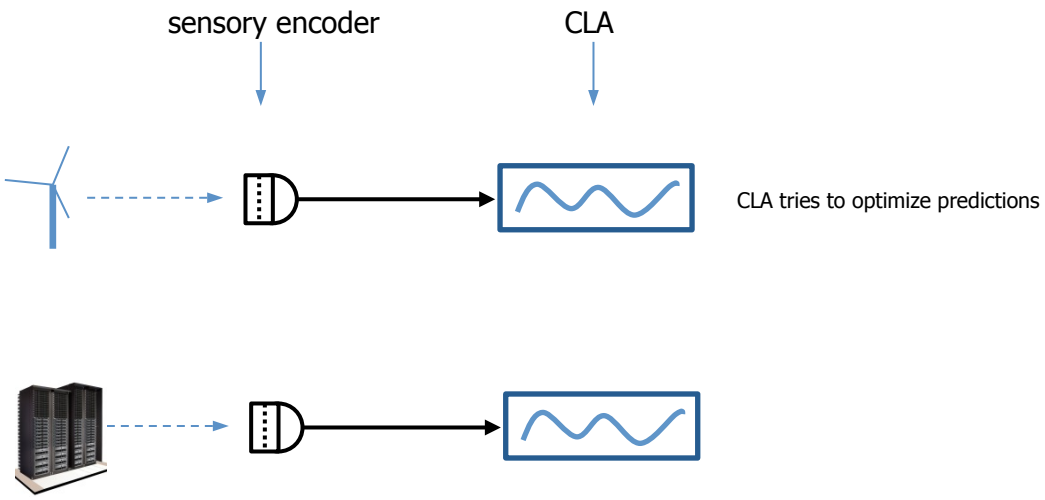
- Biological: Vision, audition, touch, proprioception
- Non-biological: M2M data, IT data, financial data, etc.

Can be understood in a single region

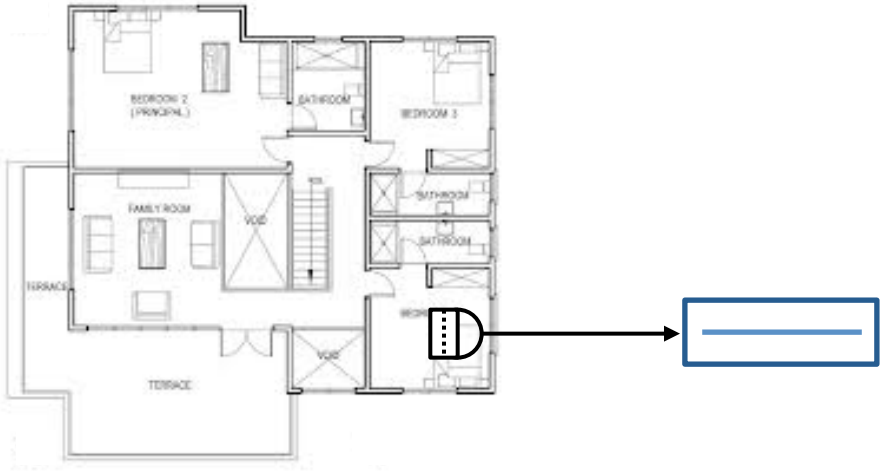
Must work in a hierarchy

Will be based on CLA principles

One extreme: Grok, dynamic world no behavior



Other extreme: Static world

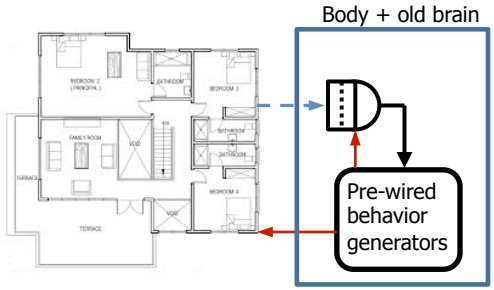


Behavior is needed for any change in sensory stream

1) Move sensor: saccade, turn head, walk
2) Interact with world: push, lift, open, talk

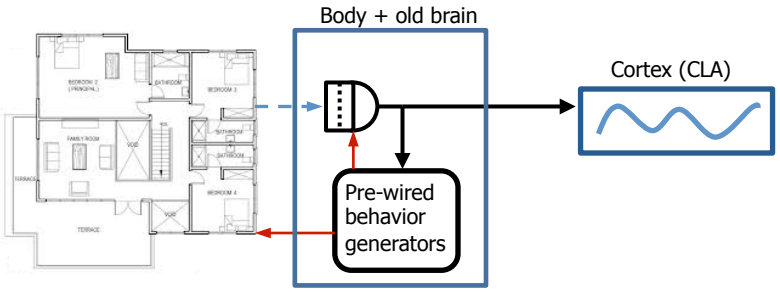
Are these the same? I think so.

All mammals have pre-wired, sub-cortical behaviors



Walking, running, eye movements, head turning, grasping, limb reflexes, breathing, blinking, etc.

Cortex appears late in evolutionary time

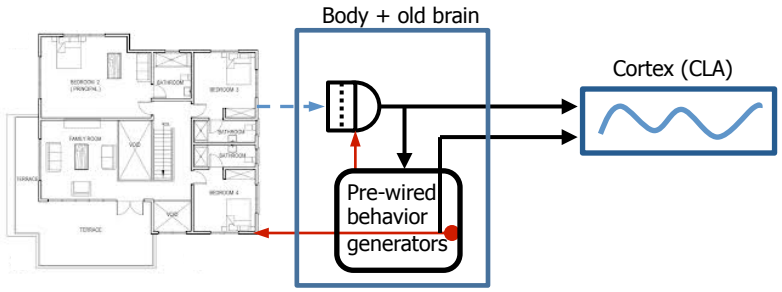


Cortex also receives sensory input.

As shown, it can learn patterns and make predictions, even in a static world.

Cortex not useful yet.

Cortex receives a copy of motor commands



Motor commands are another type of sensory input that helps cortex predict better.

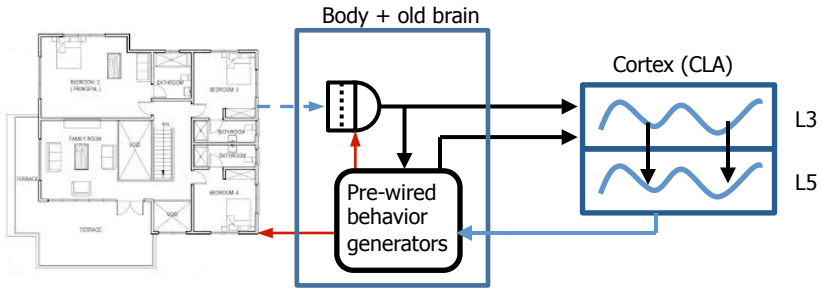
E.g. when approaching an obstacle the body might turn left or right. The CLA will learn this and make two predictions when it sees an obstacle. With copy of motor command CLA will make correct prediction.

CLA learns sequences of sensory-motor pairings.

$Sense_1 + Motor_1 \rightarrow Sense_2 + Motor_2$

$Sense_2 + Motor_2 \rightarrow Sense_3 + Motor_3$

Cortex learns to control lower motor region



L3 projects to L5.

L3 to L5 transform is unknown.

Simple explanation: column activations are the same, L5 is copy of L3 sequence.

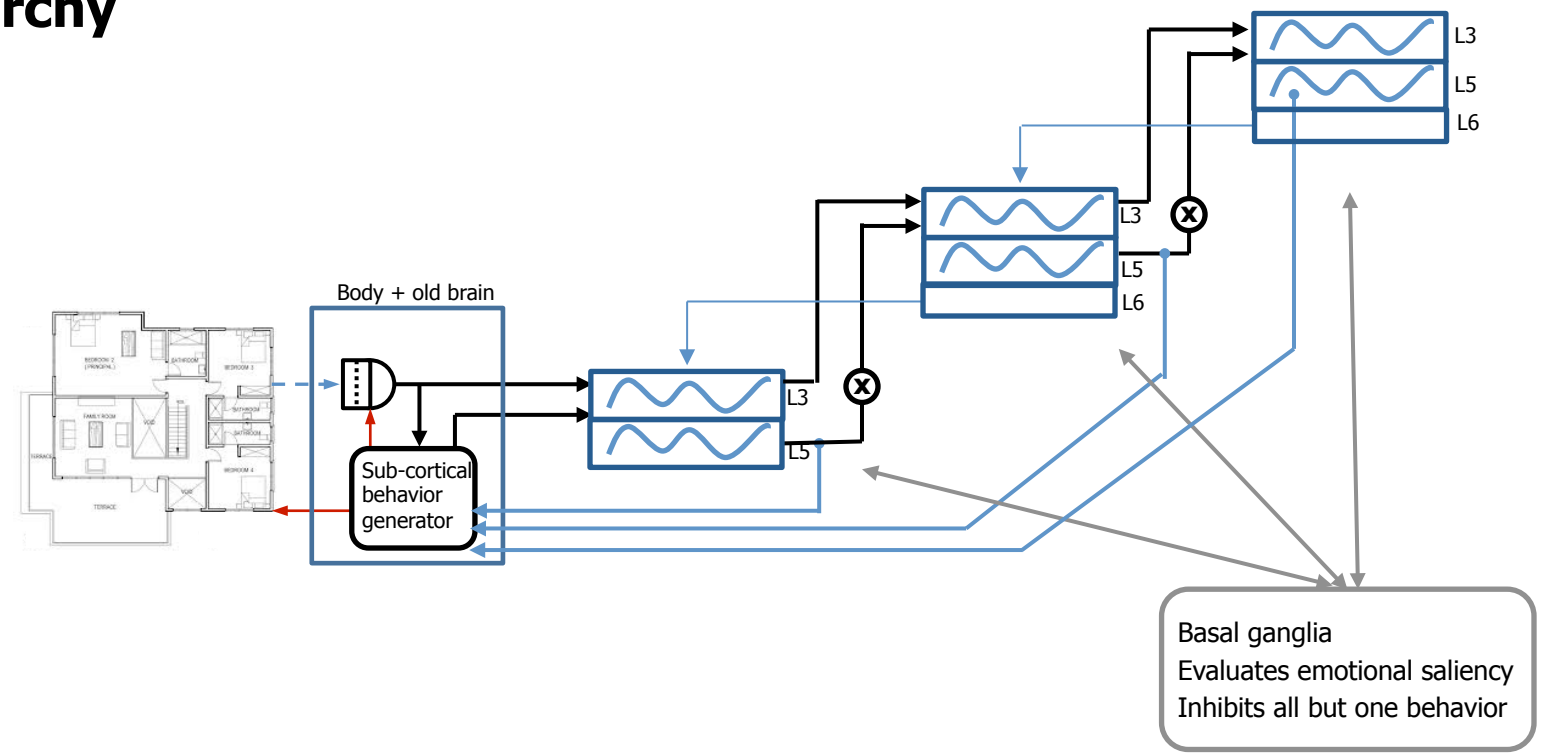
L5 associatively links to sub-cortical behavior.

Cortex can now invoke behaviors "when it wants to", "in novel sequences".

Why L5 in addition to L3?

- L5 cells are similar but different than layer 3 cells
- Add precise timing to L5
- L3 temporal pooling, L5 no temporal pooling
- Disable L5 to stop behavior
- Disable L5 to let lower regions control behavior

Hierarchy



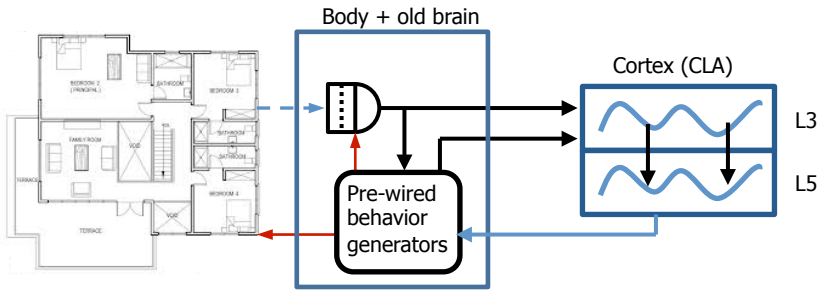
Hypothesis: Each region treats the region below as the first region treats the pre-wired region.

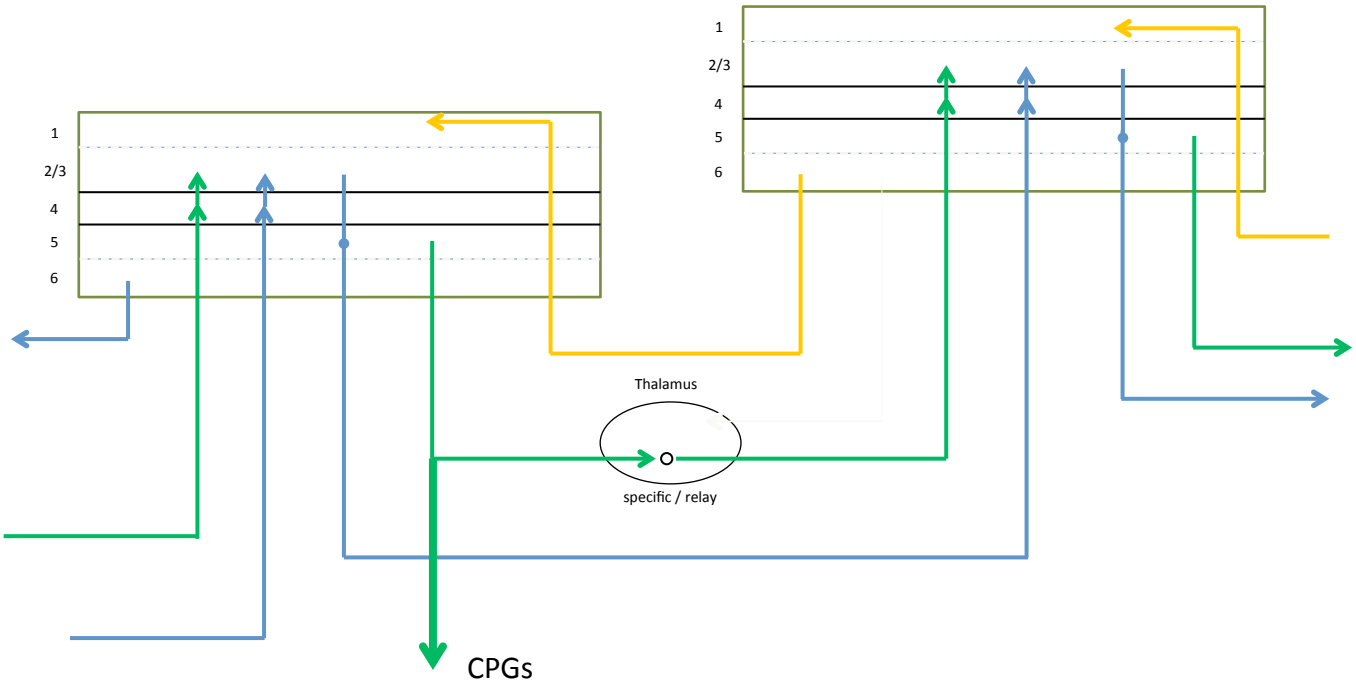
Therefore: Understand one region, understand them all.

Why hierarchy?

Same reason as for inference: convergence of multiple senses and multiple behaviors.

Our goal, understand a one region sensorimotor system





Feed Forward

Feed Forward #2 (gated, attention, transform?)

Feed Back (supervised training, sequence propagation)

Motor projection ?