

Meaningful-Based Cognitive Architecture (“MBLS”)

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Neural Symbolic Gap

- **Neural Network** – phenomenal image processing and reinforcement learning
- **Child** – phenomenal causal learning with few examples (eg, Gopnik)



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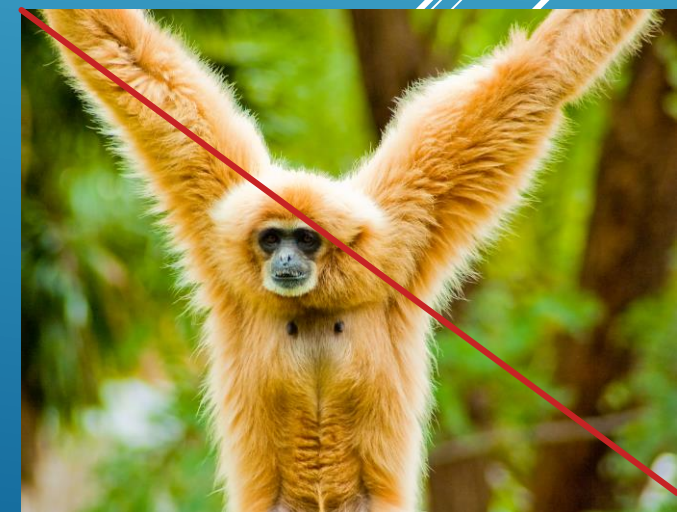


“panda”
57.7% confidence

“gibbon”
99.3 % confidence

Goodfellow, I.J., Shlens, J. and Szegedy, C. (Google Mountainview), Explaining and Harnessing Adversarial Examples, ICLR 2015.

It's still a Panda – and the 3 year old boy would know this!!
(and.... 3 year old only needs 1 or 2 photos for training, not 1000s)





Deep Learning Neural Network

Pattern Recognition
→ Recognize the World


Need 1000's examples for learning

3 Year Old Human Child

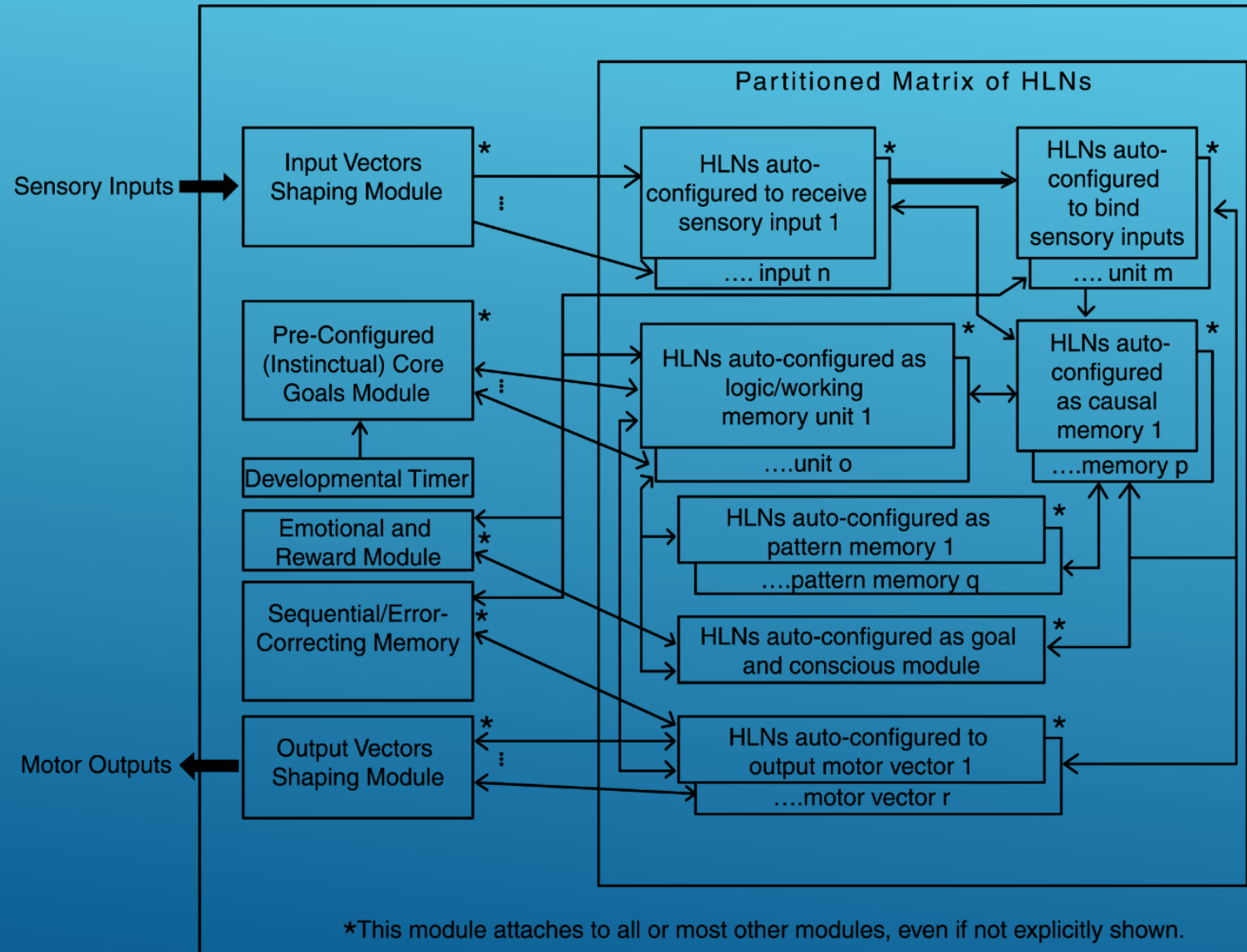
Model Building +also Pattern Recognition
→ Explain the World

A few examples enough

MBLS – Meaningful-Based Cognitive Architecture

1. Pragmatic solution to the neural-symbolic problem
 2. Pragmatic technology -- not just pattern recognition but comprehension + learning from a few examples
 3. MBLS as model re strategy towards brain disorders (eg, schizophrenia)
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- A series of white lines of varying lengths and orientations are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

Meaningful-Based Cognitive Architecture



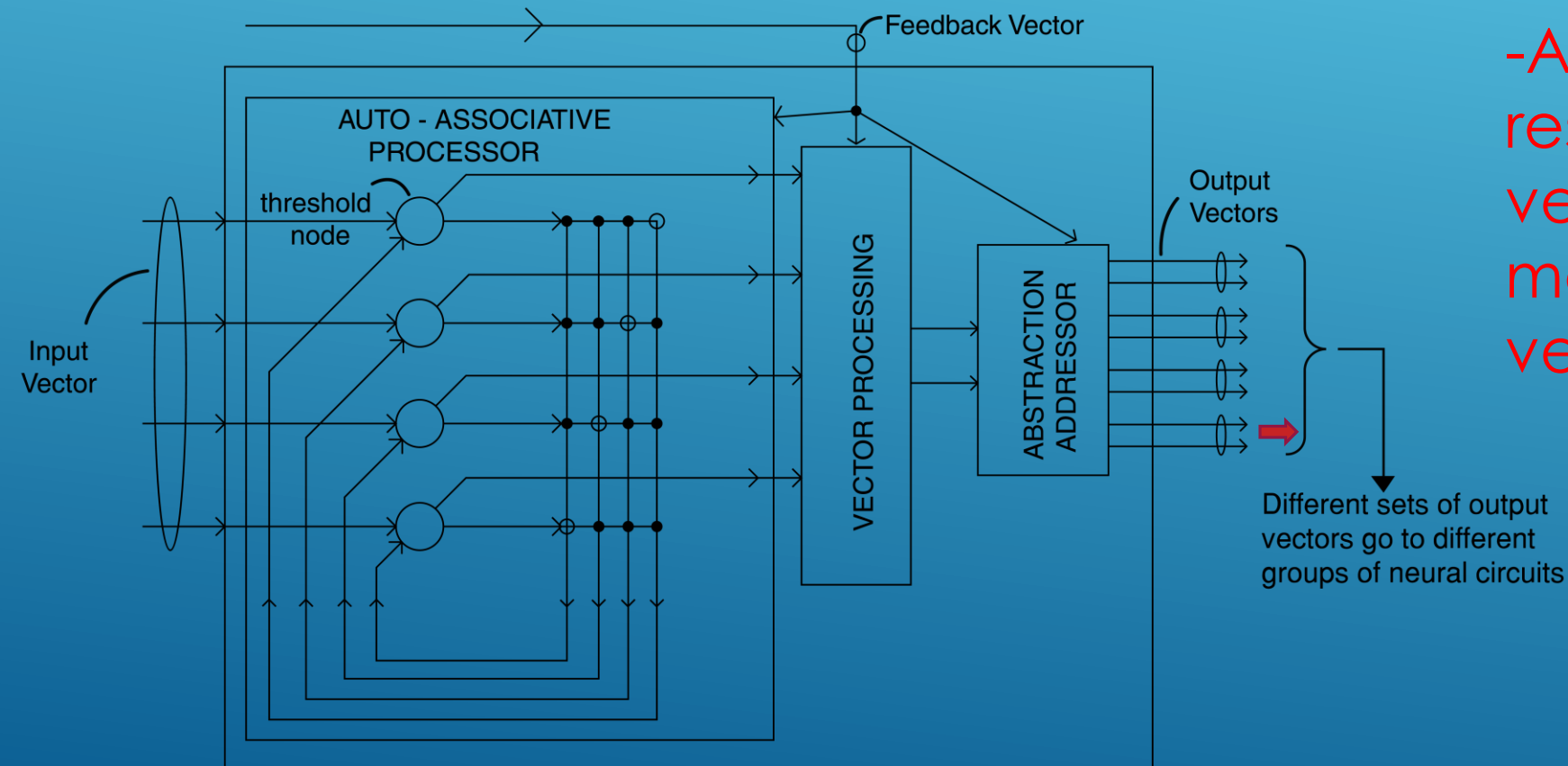
15 Minute Introduction to MBLS

1. HLN (Hopfield-like Network) is basic unit of MBLS
2. Causal Memory
3. HLN's forming Logic/Working Memory groups
4. Practical example to put it all together
5. Model of brain (devp't psychotic disorders in *H. sapiens*)

Hopfield-like Network == HLN

-Auto-Associative Processor is a pattern recognizer

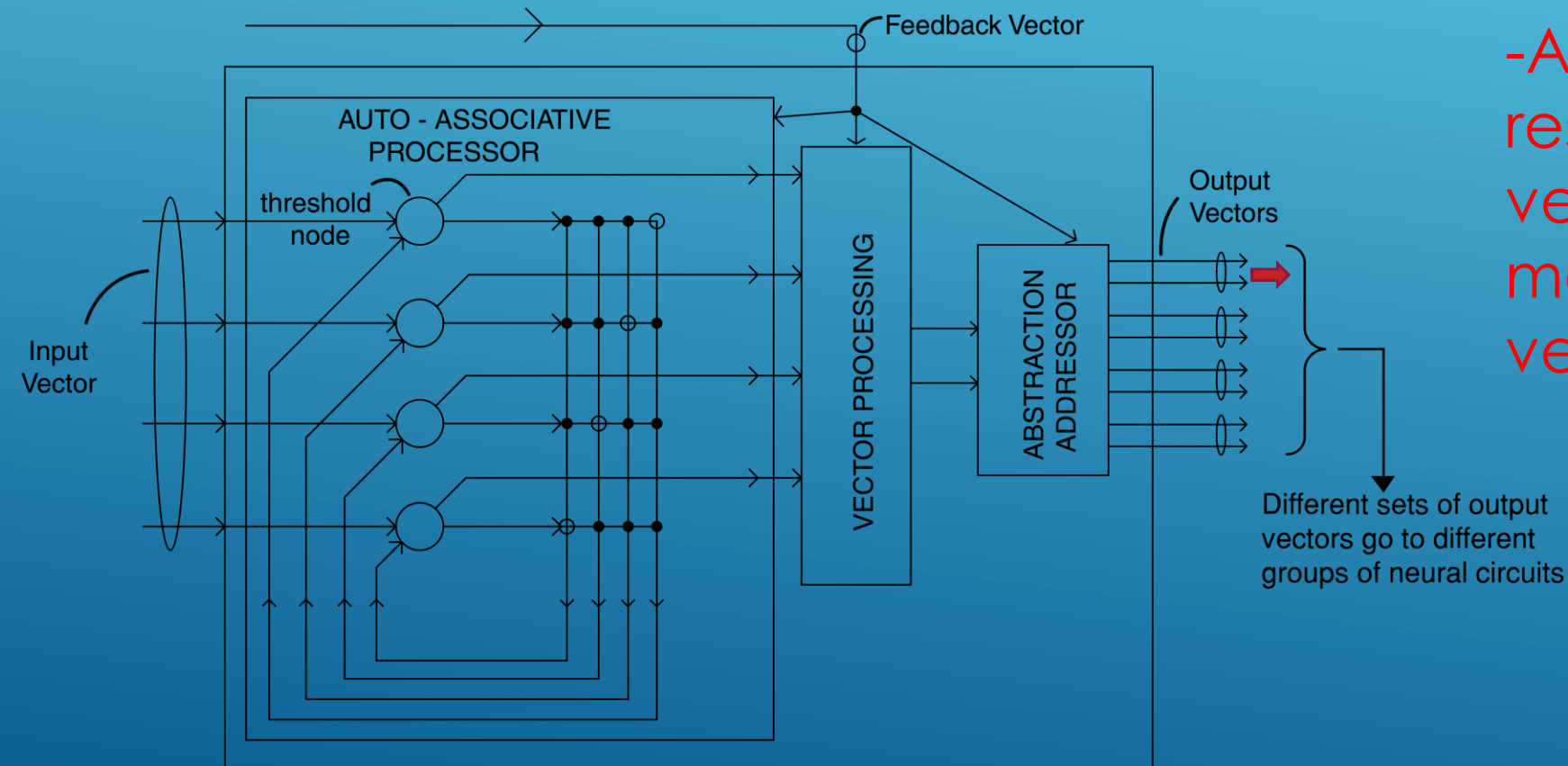
-Abstraction addressor in response to the feedback vector, decides which of many possible output vectors to use



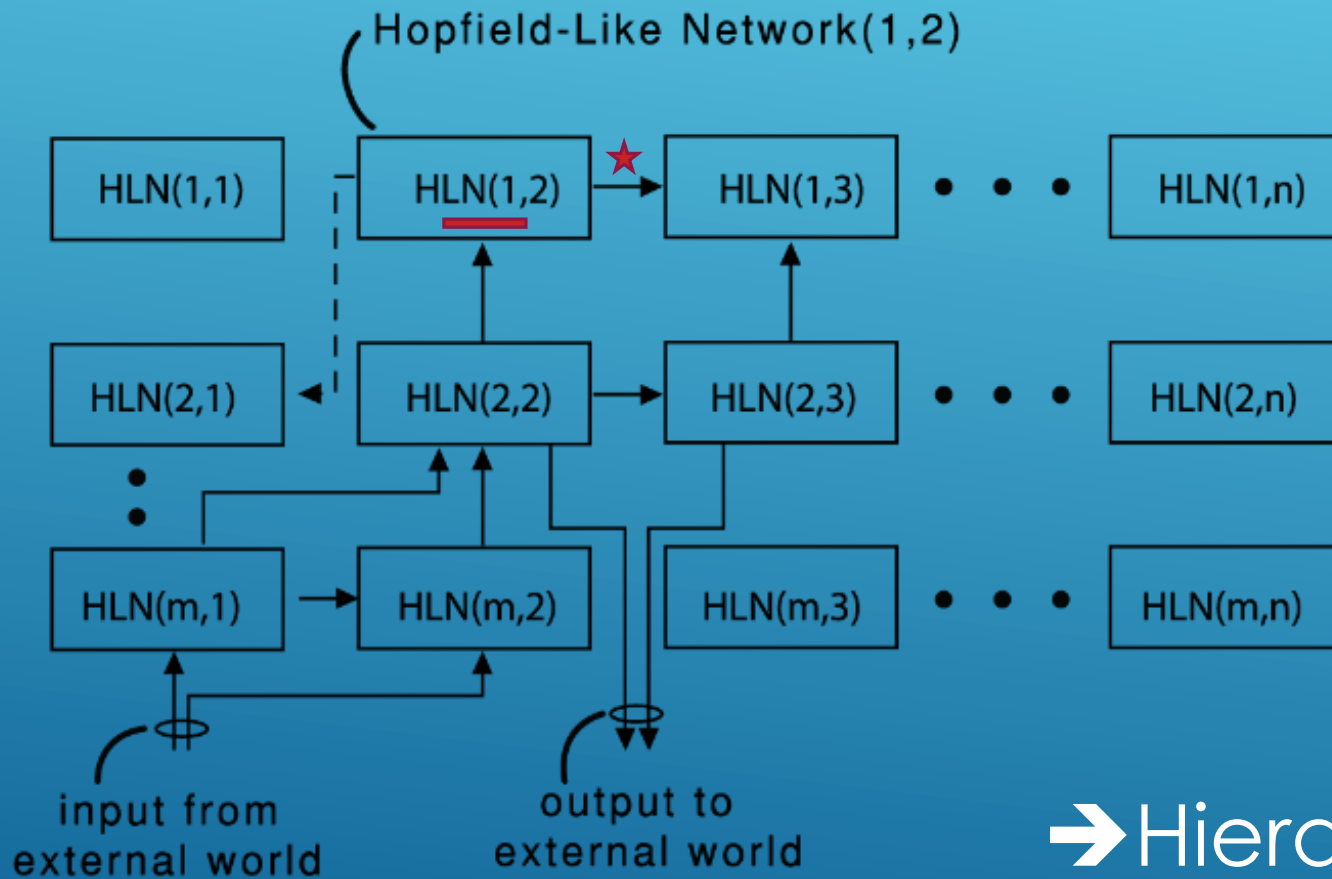
Hopfield-like Network == HLN

-Auto-Associative Processor is a pattern recognizer

-Abstraction addressor in response to the feedback vector, decides which of many possible output vectors to use



Matrix of HLN



-Core structure of MBLS is a matrix of HLN
-**HLN(1,2)** attaches to both **HLN(1,3)** and.....

→ Hierarchies and other topologies easy to organize

Hierarchies of Pattern Recognizers (== HLN) can do Pattern Recognition

- ❑ Work by others – Hawkins, Kurzweil, George and others on “pattern recognizer” hierarchies (the pattern recognizer in the MBLS is effectively the HLN unit)
- ❑ Various hierarchies of pattern recognizers can recognize, for example, from lines to letters to words to ideas associated with those words

Weights of Connections change....

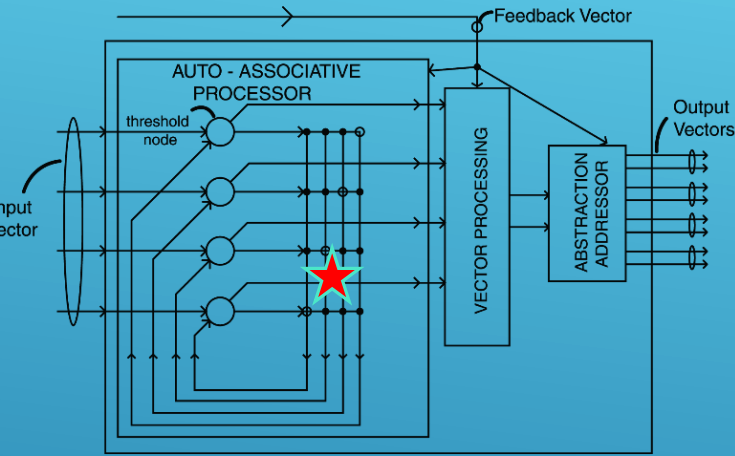


Figure 2 Hopfield-Like Network (HLN)

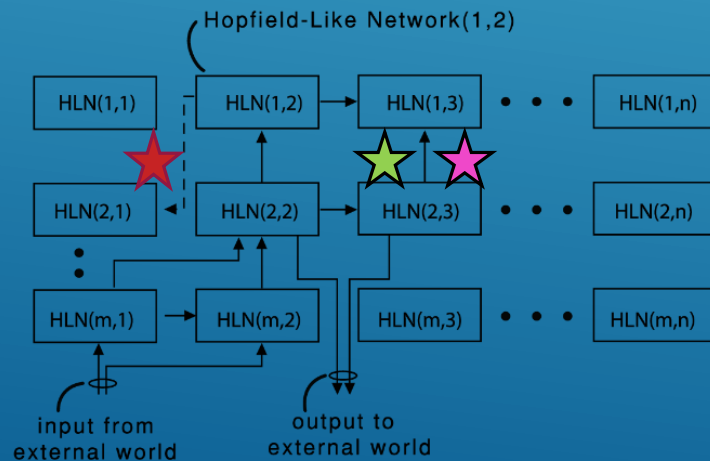
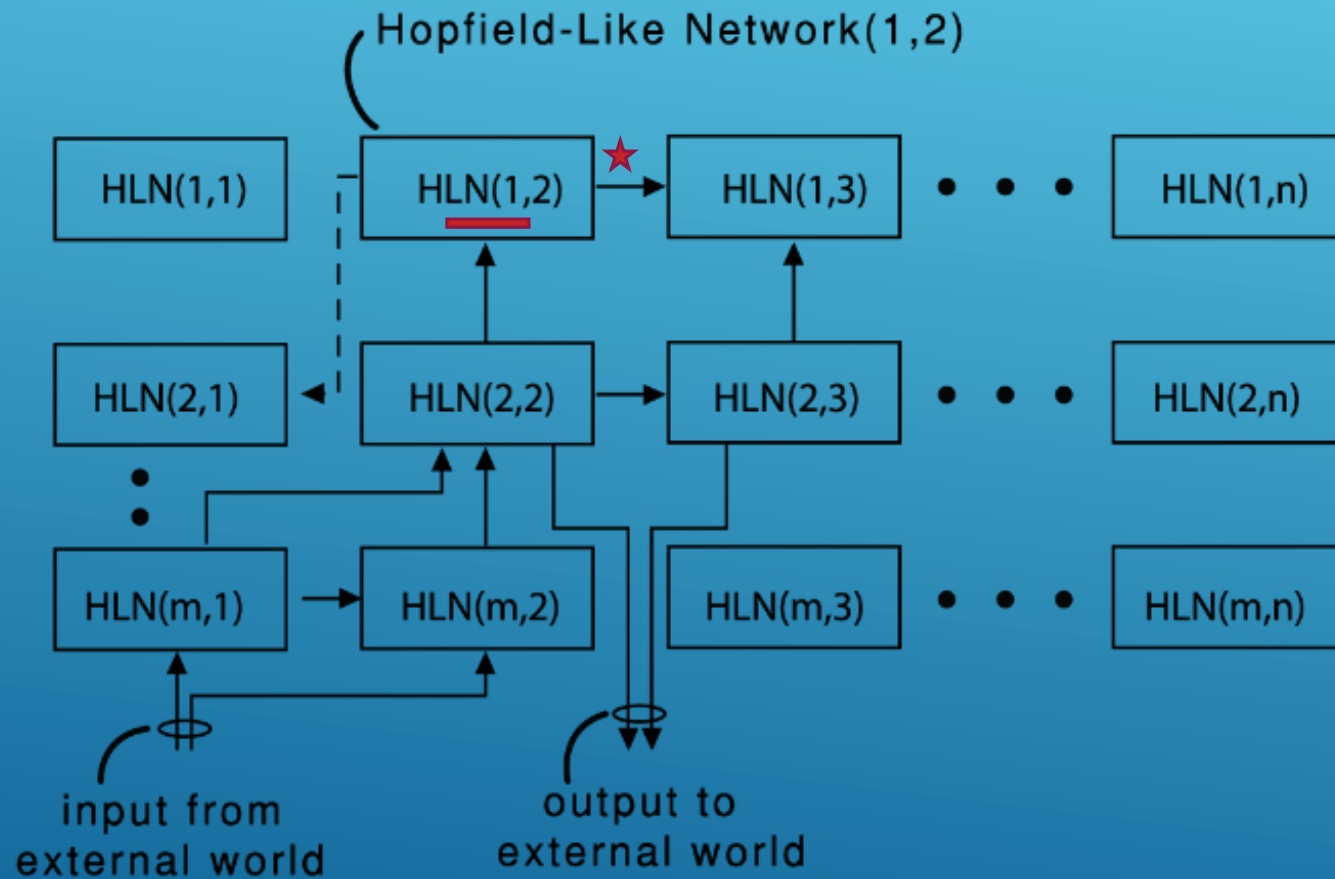


Figure 1 MBLS Core Structure

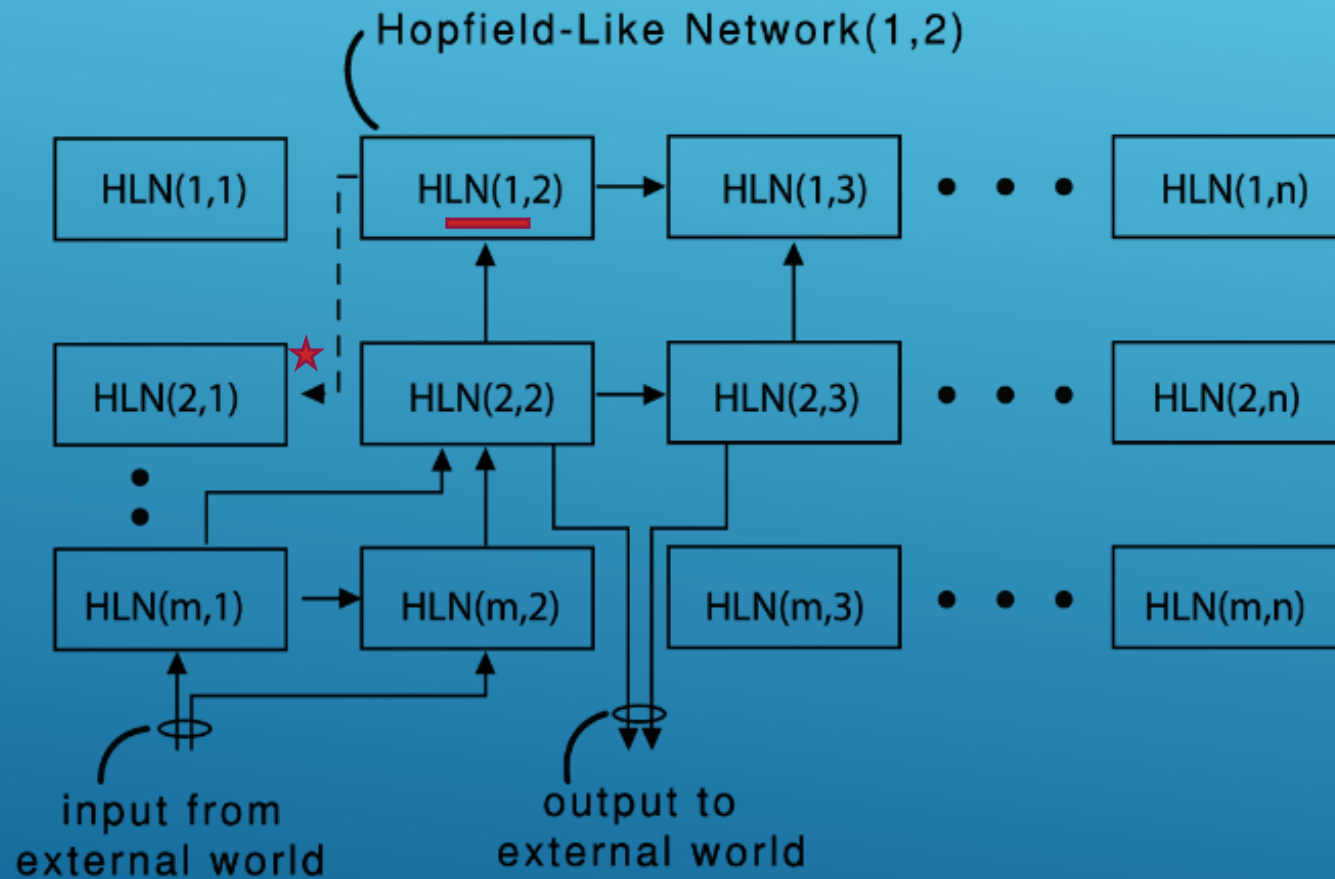
- ★ Weights within individual HLN auto-
assoc processor ← *gradually*
- ★ Weights between HLNs ← *gradually*
as in conventional ANN
- ★ Weights between HLNs ← *large,*
long-term changes to form more
discrete logical relations
- ★ Weights between HLNs ← *extreme*
rapid reconfigurations

Weights between HLN's \leftarrow *extreme rapid reconfigurations*



\leftarrow **HLN(1,2)** attaches to both **HLN(1,3)** and **HLN(2,1)**

Weights between HLN's \leftarrow *extreme rapid reconfigurations*

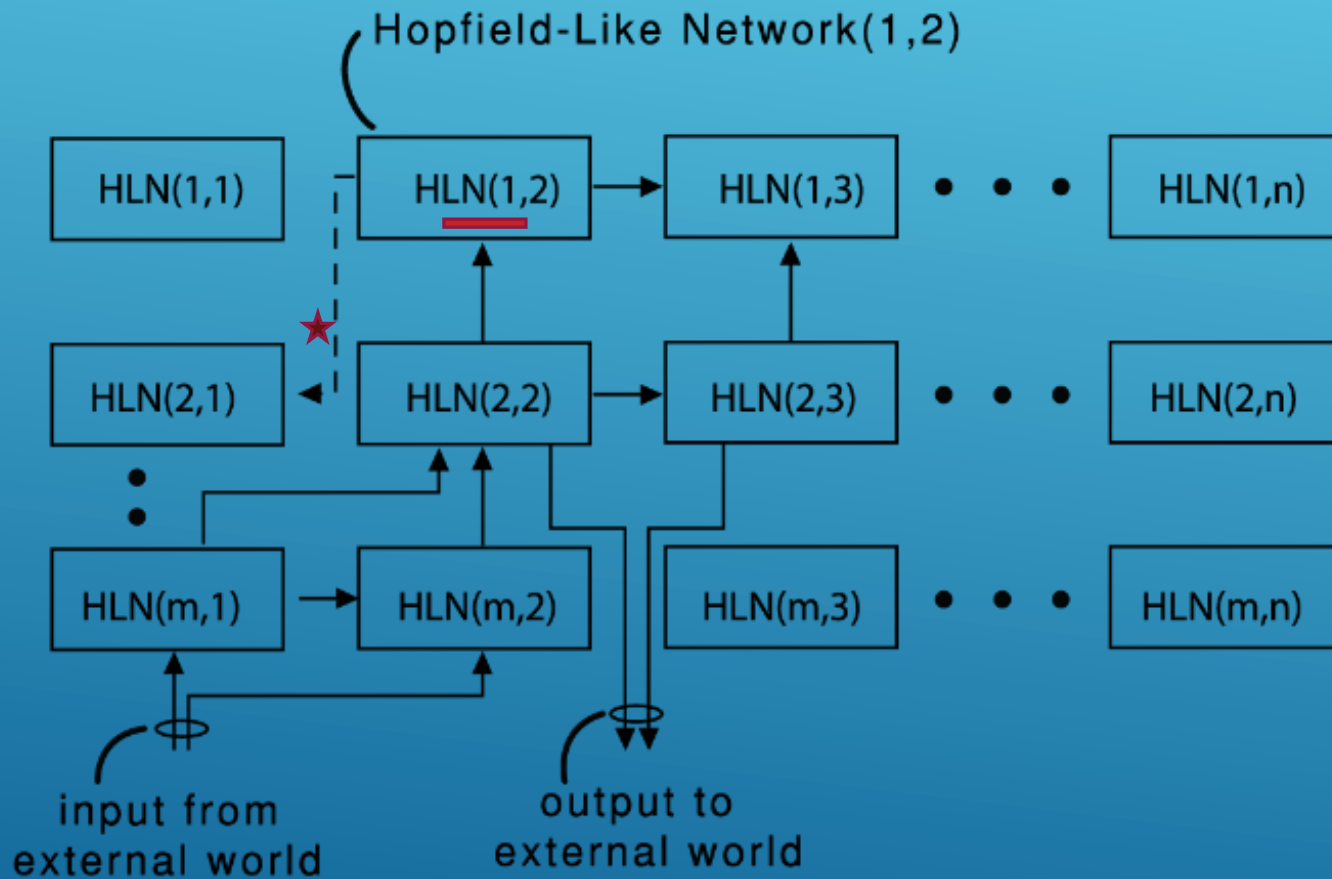


*Rapid
Reconfiguration of
HLNs possible – we
can try a number of
reconfigurations*

Which HLN's do we connect to other HLN's?



Try to Maximize Meaningfulness



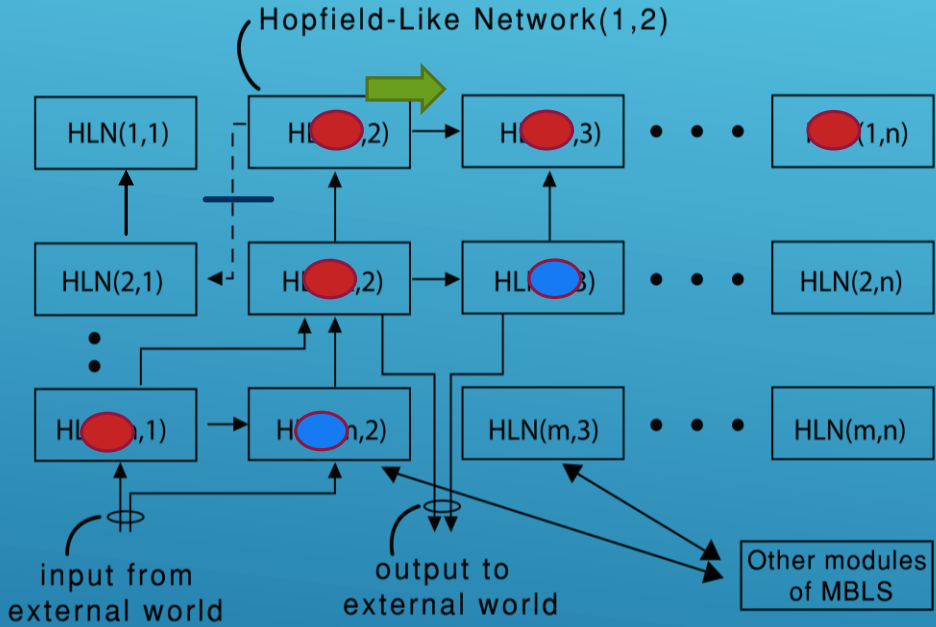
What is *Meaningfulness* ?

$$H = -\sum_i P(x_i) \log_2 P(x_i) \quad \leftarrow \text{Shannon entropy}$$

$$M = 1/H \quad \leftarrow \text{Meaningfulness}$$

Unfair coin: Tails, Tails, Heads, Tails, Tails, Tails
Therefore, low entropy, high meaningfulness

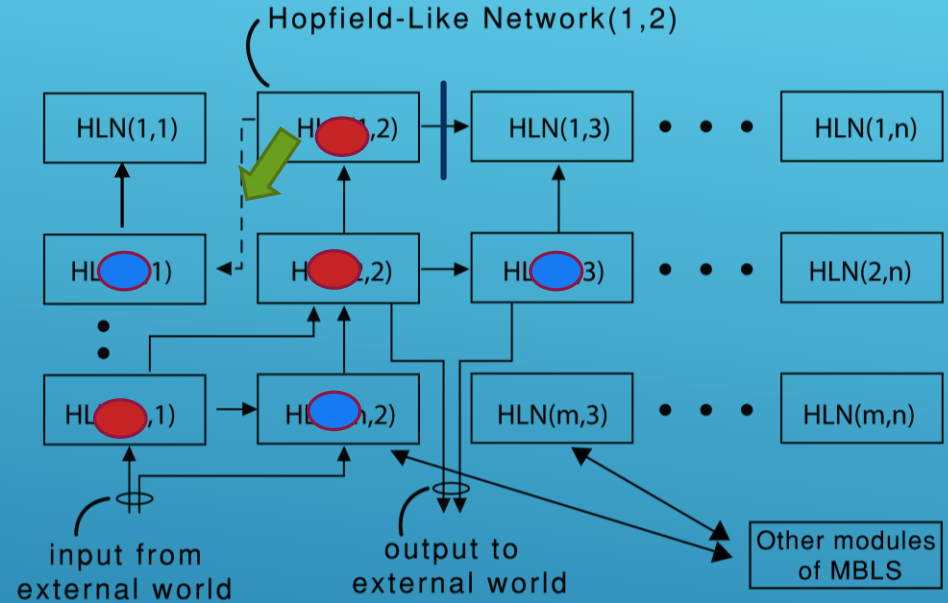
Meaningfulness – via Shannon Entropy



Reconfiguration A

5 HLN's 'On', 2 HLN's 'Off'
 $p(\text{ON})=5/7$, $p(\text{OFF})=2/7$
 $H=0.86 \rightarrow \mathbf{M=1.2}$
(via Counting: 5 on

VS.
VS.
VS.
VS.

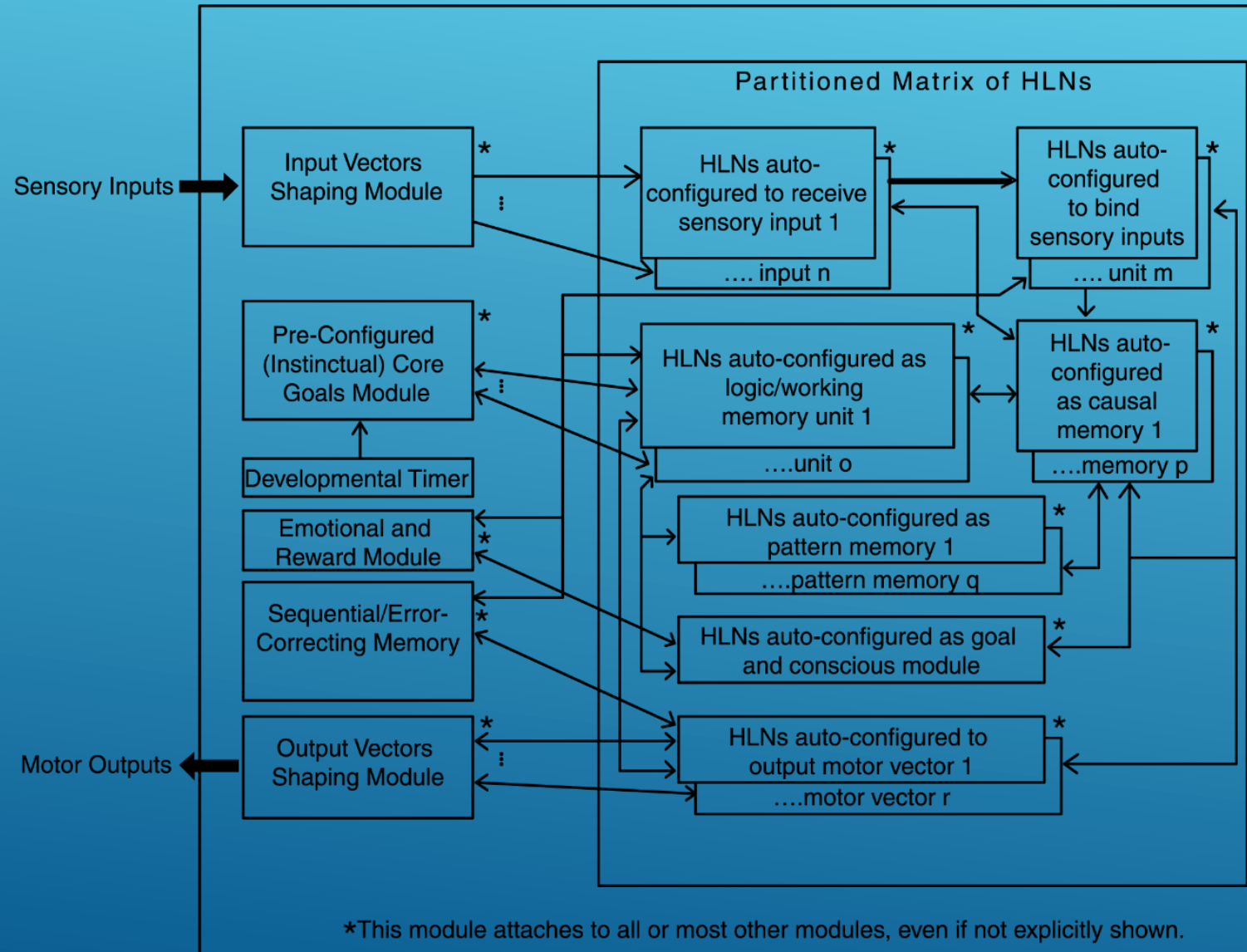


Reconfiguration B

3 HLN's 'On', 3 HLN's 'Off'
 $p(\text{ON})=3/6$, $p(\text{OFF})=3/6$
 $H=1.0 \rightarrow M=1.0$
via Counting: 3 on)

3 H
p(0
H=
vic

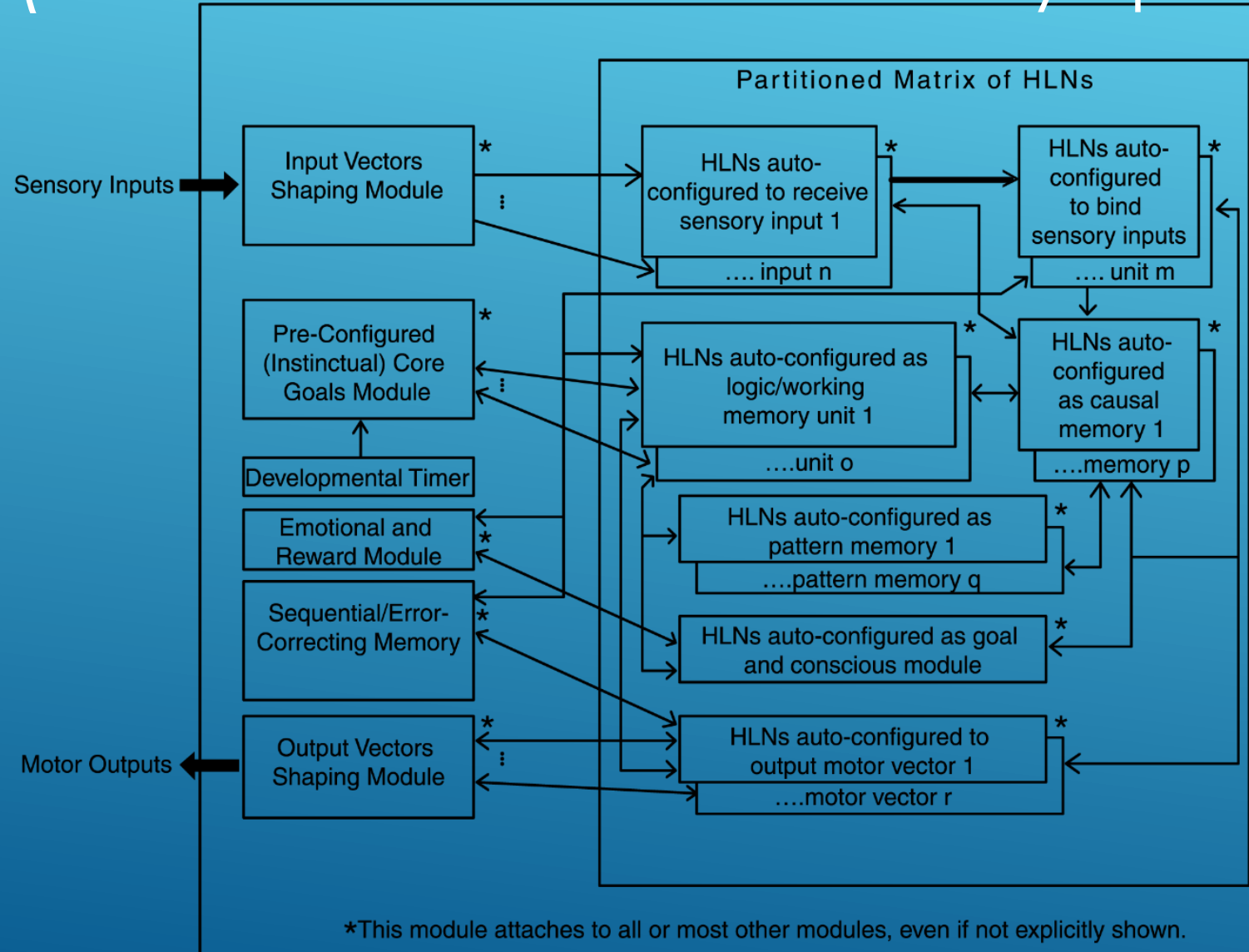
Meaningfulness – good idea but intractable ?



← Infinite time for millions of HLNs to auto-configure to this very useful configuration

Meaningfulness – Polynomial-Time Solution

(Real Time Solution actually quite feasible)



← Basic architecture of system, ie, relations between HLN's auto-configured via design via default weights and default pathways/topology

- (Biological analogy – genetic pre-configuration of central nervous system – cortical columns all look similar but specializations and groupings)

15 Minute Introduction to MBLS

1. HLN basic Unit of MBLS

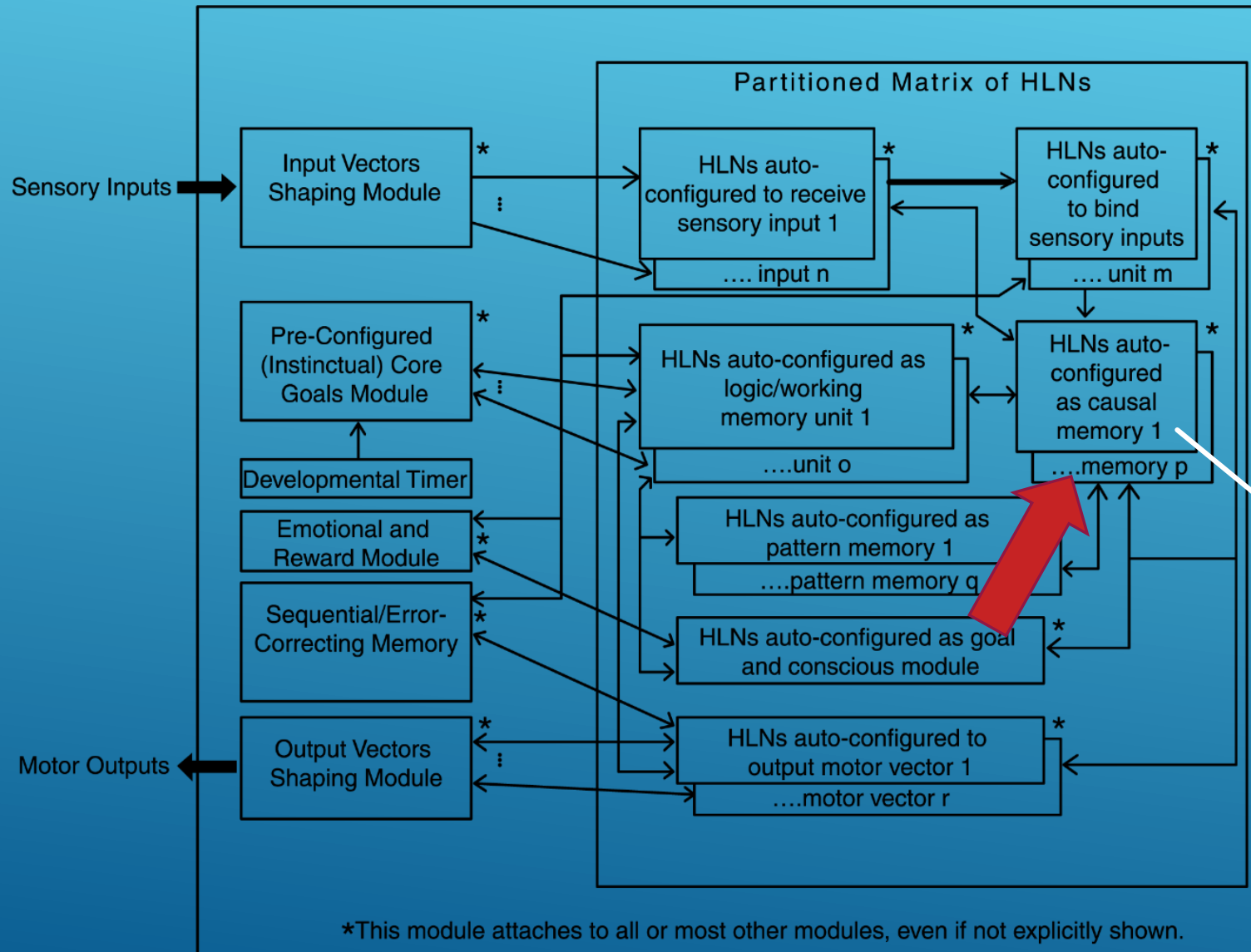
2. Causal Memory

3. HLN's forming Logic/Working Memory groups

4. Practical example to put it all together

5. Model of brain (devp't psychotic disorders in *H. sapiens*)


Causal Memory



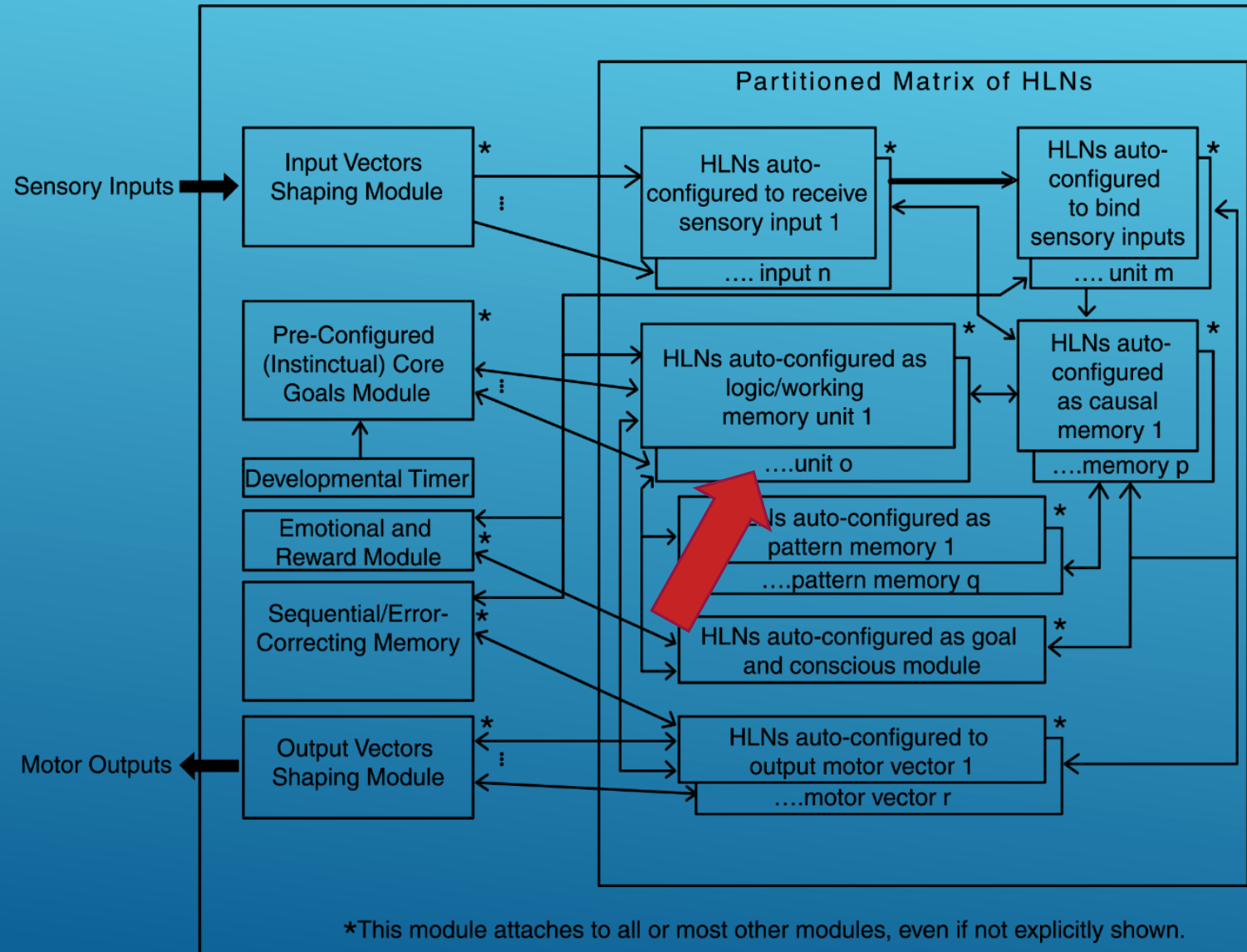
Many of the HLNs configured as causal memory (world models, procedural info, declarative info, episodic info)

What event follows another event, what spatial feature leads to next spatial feature, etc

15 Minute Introduction to MBLS

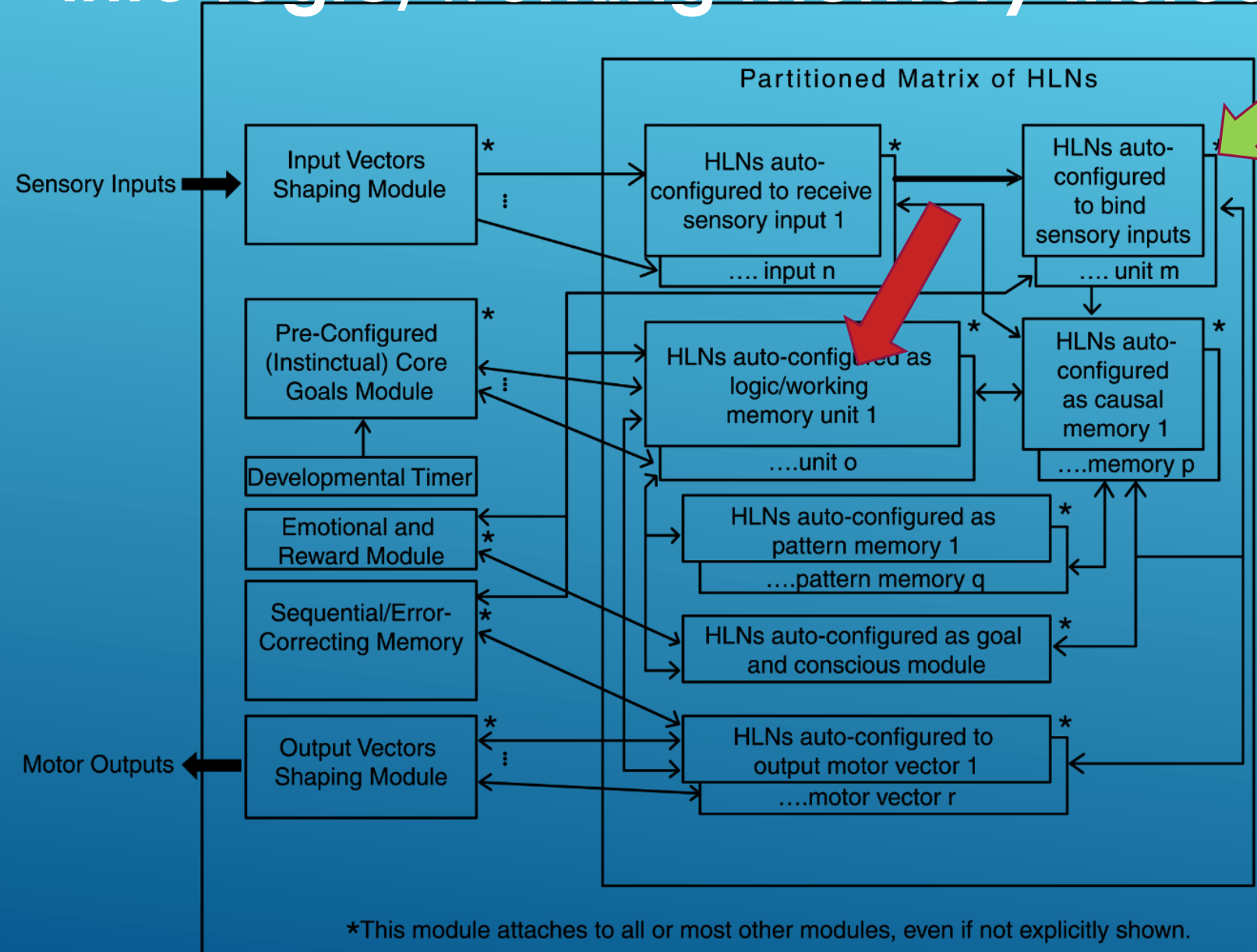
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Logic/Working Memory Units



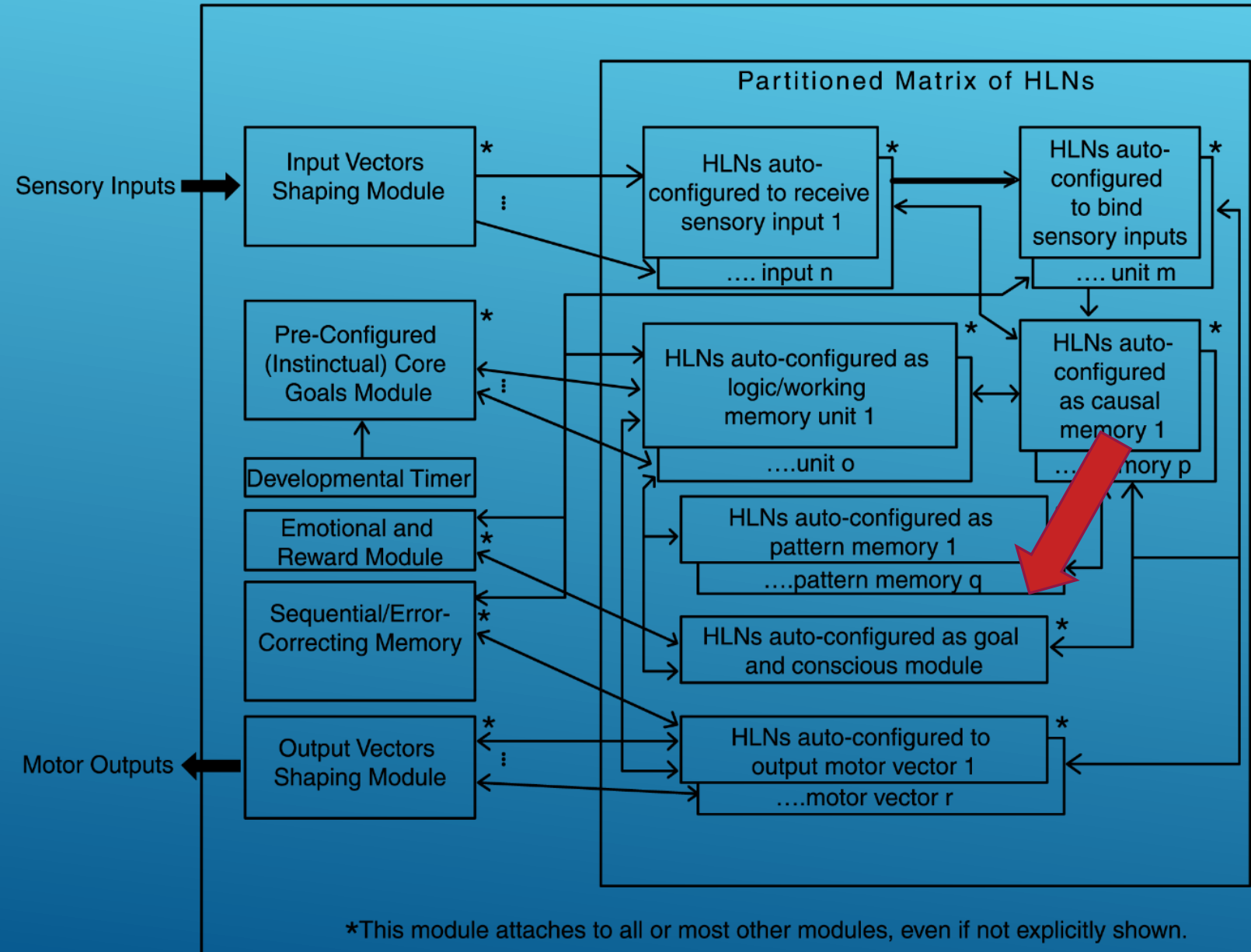
HLNs auto-
configured via
default weights
as logic/working
memory units

Feed vector from logic/working memory unit back into logic/working memory instead of sensory input



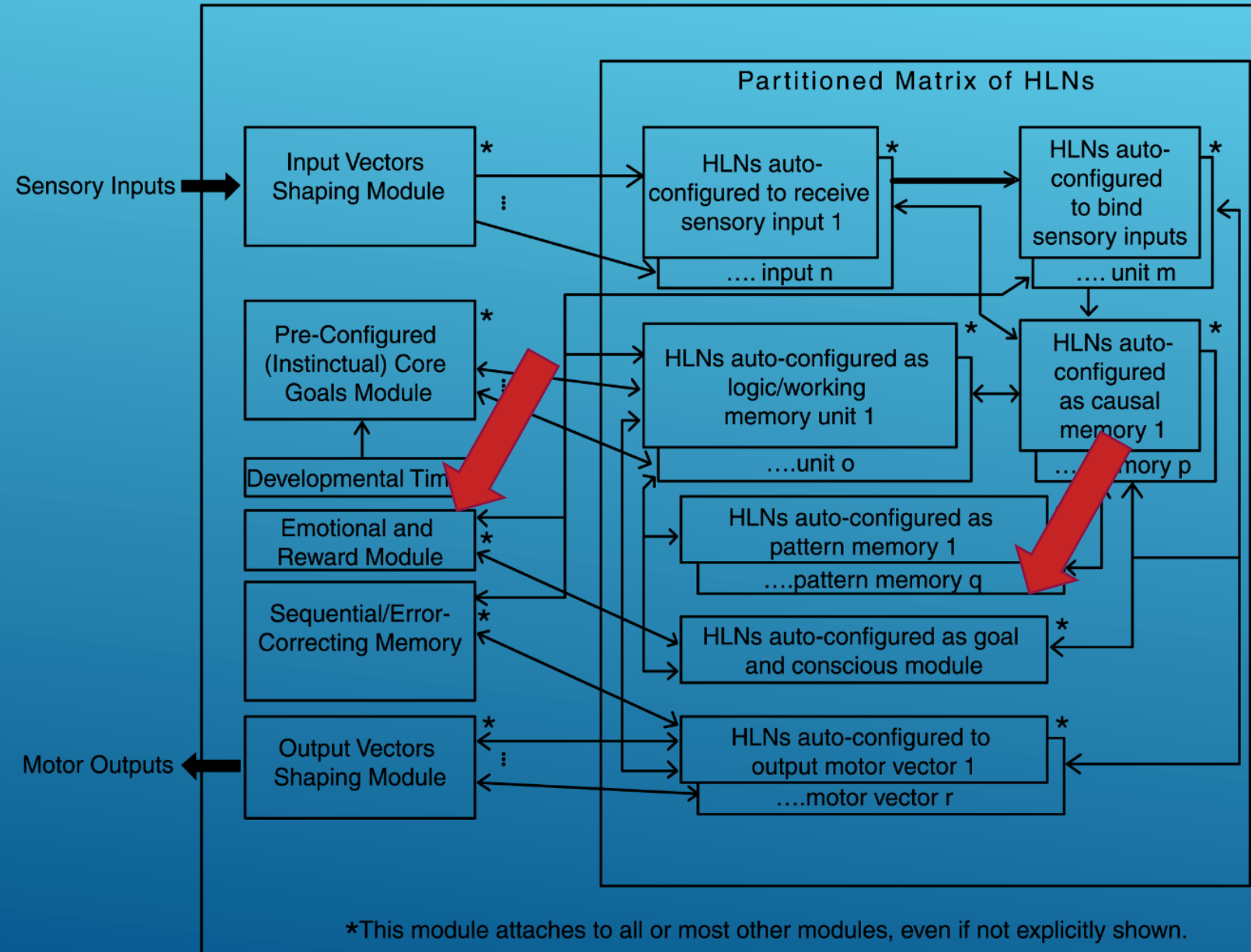
'Thought-like' – now processing internal memories rather than external sensory input vectors

Store actions of logic/working memory



Advantage – helps to guide future actions and logical operations. (Also solves part of the 'black box' problem.)

Rare Events can be Important Events to Learn



Solves much of the 'class imbalance' problem (and overfitting in attempts to fix).

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Example: Hiker lost in the woods.....



Search and rescue robot dispatched to the forest



← *Controlled by an MBLS*

Note: This is hypothetical. It would take a simulation of 100 million HLN's and a large effort developing the basic algorithms to create such an MBLS.

- MBLS search & rescue robot **goes into the forest**
- Environment **full of noise** with a variety of **faint signals**



- MBLs start looking for recognition of some inputs with patterns it has seen before (or been transferred)
- Any matches?
- Reconfigure some HLN
- Ahhh...2 input sensory vectors cause higher Meaningfulness



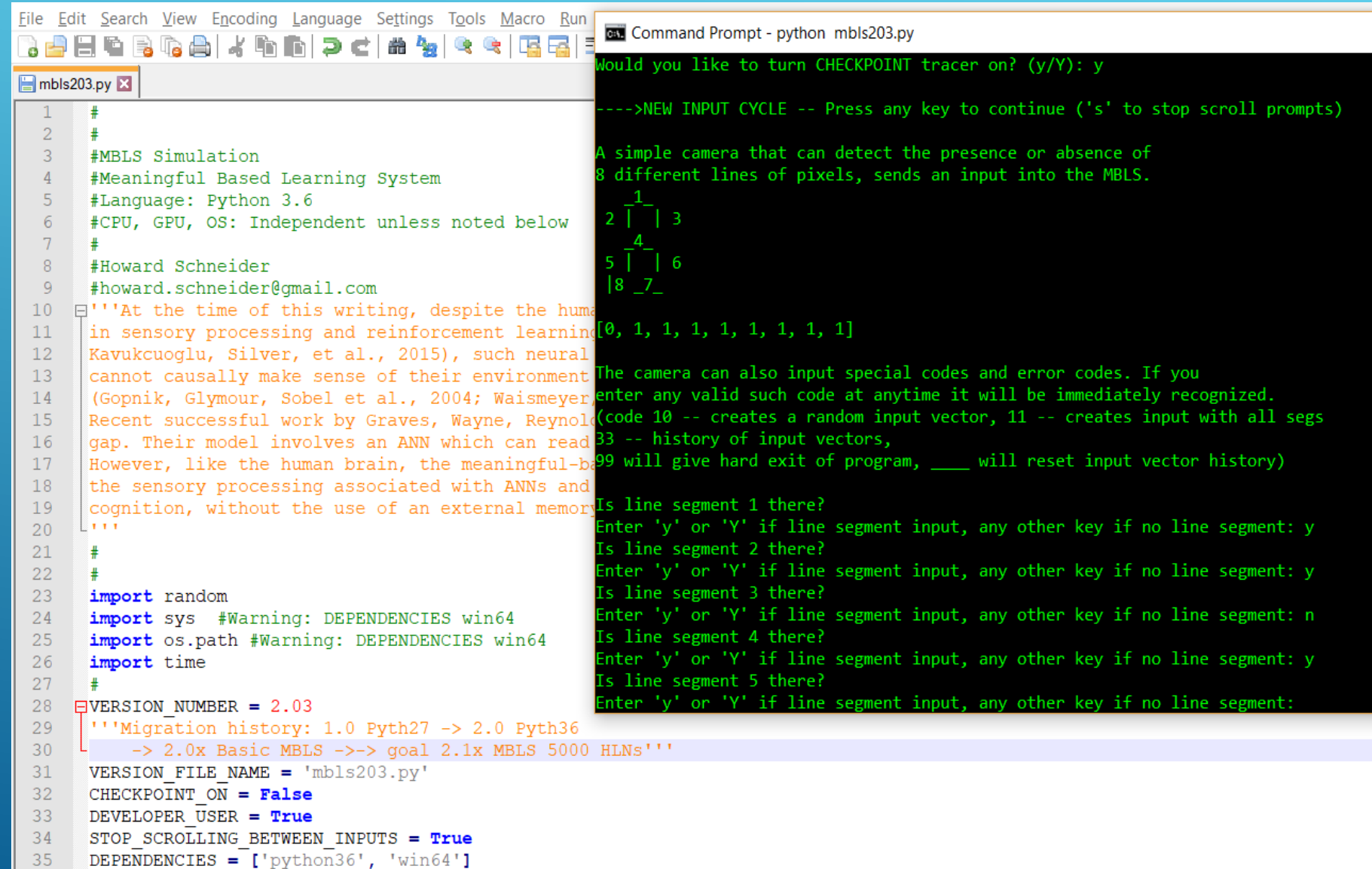
- High M sensory input vectors:
- #1 -Sound from southwest that matches with human cry for help and with bird mating call
- #2 -Odor from north that matches with commercial perfume/cologne
- Processed sensory input vectors sent to Logic/Working Memory unit (can compare vectors and create vectors, output action,...)
- Better match of odor sensory input with goal vector → robot directed to north

- After a few more minutes to the north – success – the lost hiker is found



Simulation of the MBLs

Transition to 5000 Simulated HLN's --



The image shows a screenshot of a Python script named `mbls203.py` in a text editor, alongside its execution in a Command Prompt window.


Python Script (`mbls203.py`):

```
1 #
2 #
3 #MBLS Simulation
4 #Meaningful Based Learning System
5 #Language: Python 3.6
6 #CPU, GPU, OS: Independent unless noted below
7 #
8 #Howard Schneider
9 #howard.schneider@gmail.com
10 '''At the time of this writing, despite the human
11 in sensory processing and reinforcement learning
12 Kavukcuoglu, Silver, et al., 2015), such neural
13 cannot causally make sense of their environment
14 (Gopnik, Glymour, Sobel et al., 2004; Waismeyer,
15 Recent successful work by Graves, Wayne, Reynolds,
16 gap. Their model involves an ANN which can read
17 However, like the human brain, the meaningful-based
18 the sensory processing associated with ANNs and
19 cognition, without the use of an external memory
20 '''
21 #
22 #
23 import random
24 import sys #Warning: DEPENDENCIES win64
25 import os.path #Warning: DEPENDENCIES win64
26 import time
27 #
28 VERSION_NUMBER = 2.03
29 '''Migration history: 1.0 Pyth27 -> 2.0 Pyth36
30 -> 2.0x Basic MBLs ->-> goal 2.1x MBLs 5000 HLN's'''
31 VERSION_FILE_NAME = 'mbls203.py'
32 CHECKPOINT_ON = False
33 DEVELOPER_USER = True
34 STOP_SCROLLING_BETWEEN_INPUTS = True
35 DEPENDENCIES = ['python36', 'win64']
```

Command Prompt Output:

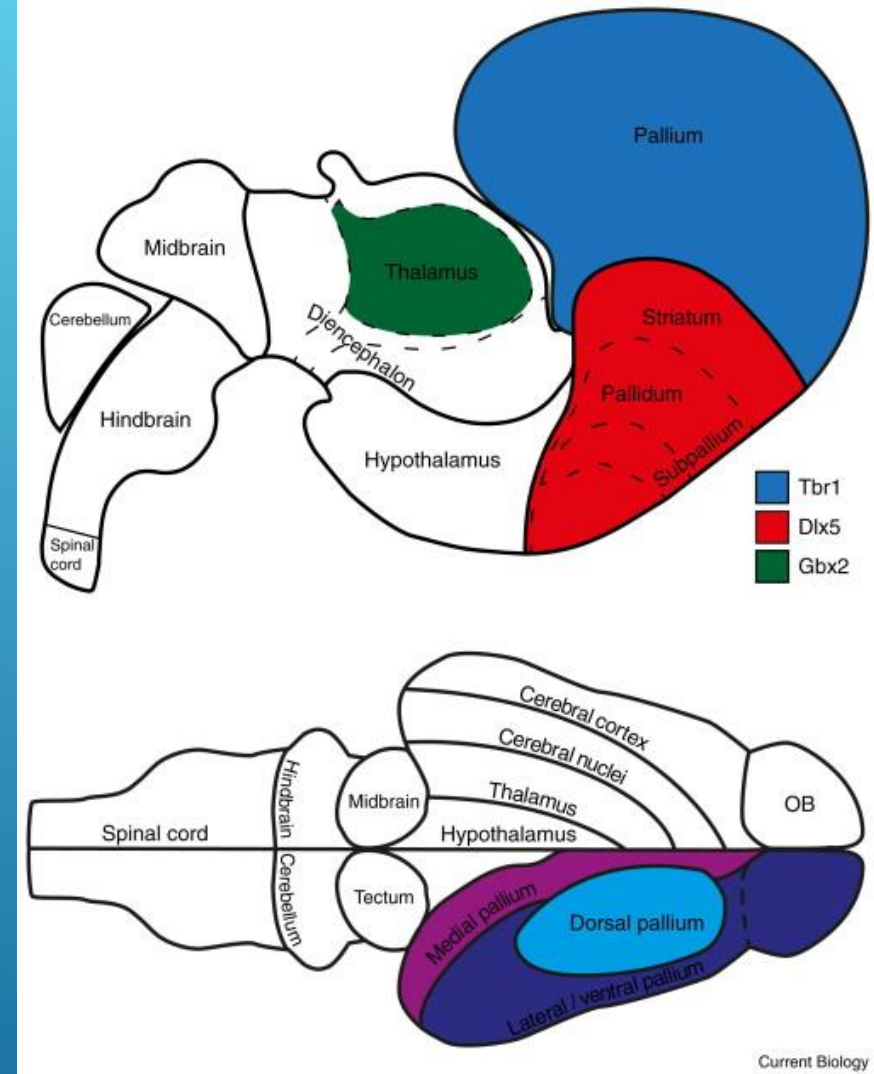
```
Command Prompt - python mbls203.py
Would you like to turn CHECKPOINT tracer on? (y/Y): y
---->NEW INPUT CYCLE -- Press any key to continue ('s' to stop scroll prompts)
A simple camera that can detect the presence or absence of
8 different lines of pixels, sends an input into the MBLs.
  1_
2 |  | 3
  4_
5 |  | 6
 |8 _7_
[0, 1, 1, 1, 1, 1, 1, 1, 1]
The camera can also input special codes and error codes. If you
enter any valid such code at anytime it will be immediately recognized.
(code 10 -- creates a random input vector, 11 -- creates input with all segs
33 -- history of input vectors,
09 will give hard exit of program, ____ will reset input vector history)
Is line segment 1 there?
Enter 'y' or 'Y' if line segment input, any other key if no line segment: y
Is line segment 2 there?
Enter 'y' or 'Y' if line segment input, any other key if no line segment: y
Is line segment 3 there?
Enter 'y' or 'Y' if line segment input, any other key if no line segment: n
Is line segment 4 there?
Enter 'y' or 'Y' if line segment input, any other key if no line segment: y
Is line segment 5 there?
Enter 'y' or 'Y' if line segment input, any other key if no line segment:
```

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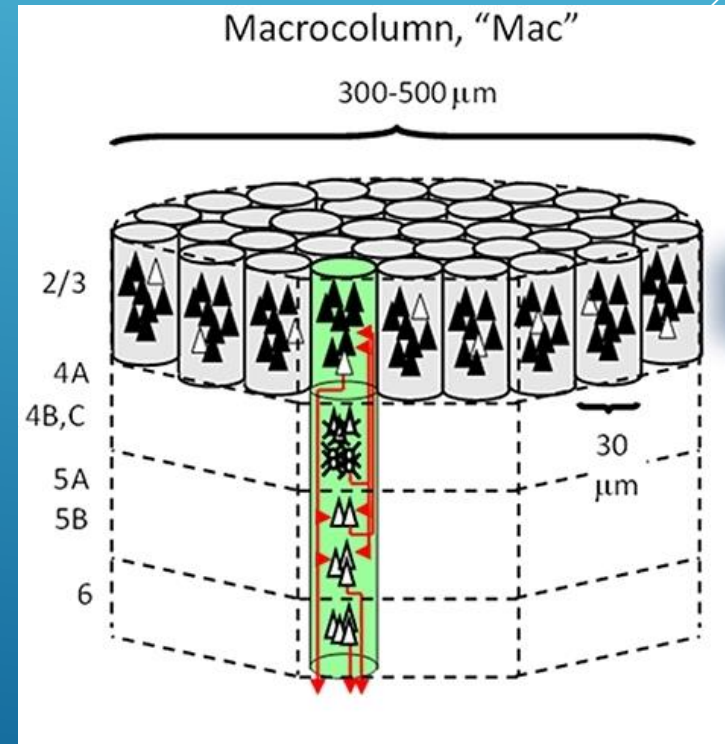
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Reptilian Brain

No cerebral neocortex, but sensory information does reach circuits in the pallium




Mammalian cerebral cortex



Model re Psychotic Disorders in *H sapiens*

- **If....** HLN's form Logic/Working Memory units (human Working Memory)
- **Then....** Much more complex configuration than rest of MBLS (rest of brain less likely for fatigue or failure)
- **Then....** Increased risk of failure to impede cognition and retrieve inappropriate memory vectors for any small issue (in humans this is 'psychosis')
- **Then...** As MBLS matures, Logic/Working Memory units stressed by more complex and powerful algorithms -- this is when risk of failure the greatest (psychosis in teenage years)
- **Solution:** More redundant methods/self-protection to Logic/Working Memory units (in humans protect Working Memory in teen years to prevent schizophrenia)
- **Caveat:** Speculative....but some evidence supports above clinically

MBLS – Meaningful-Based Cognitive Architecture

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Future Work



- ▶ Larger, more comprehensive simulation
- ▶ More formal proofs of the features of the MBLS

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