Projects *(for some of these we have previous student project files in emergent8 that you can use and propose to extend*).

1) **Simulate the effects of drugs that affect inhibition in the hippocampus**

Simulating effects of different levels of inhibition on memory in the hippocampus - e.g. to model effects of drugs such as anti-anxiety and sleep medications (benzodiazepenes which affect GABA-A receptors), or drugs that affect neuromodulation, such as dopamine, on episodic memory.

2)  **Simulate Synesthesia.** Synesthesia occurs when the experience of one sense (e.g. the color green) involuntarily triggers another sensory experience (e.g. taste). This is thought to occur through either top-down feedback from multimodal integration areas or from cross activation of sensory areas (van Leeuwen et al., *J. Neuroscience,* 2011). Show how both mechanisms can result in synesthesia and whether they make different predictions, using a Stroop task in which the model either has to name the actual color of a stimulus or the color-associated with the synesthetic representation.

3) **Feedback and Feedforward Projections between V1 and IT cortex**. The object recognition model we considered in class considered only bidirectional connections between each level of the hierarchy and the one above/below it, while the anatomy suggests that there are also projections from lower levels that project to higher levels (ie direct projections from V1 and V4/IT and back). Add these connections with different types of topographies and explore their influence on the model’s object recognition.

4) **Explore different learning rules (Go version, requires programming)**. The self-organized and error-driven learning rules you have been using rely on the XCAL learning rule. You could alter this to test other forms of learning rules or other assumptions while simulating any of the projects that you have completed in the class, by modifying the associated Go code in ~/go/src/github.com/ emer/leabra/leabra/learn.go and/or the DWt function in ~/go/src/github.com/ emer/leabra/leabra/prjn.go .

5) **Hierarchical selection of task-sets in prefrontal-basal ganglia networks**. Modify the model of Collins & Frank 2013 (see executive function chapter) to allow it to better guess which set of task rules applies in a novel context. This is a relatively advanced project; we can discuss in more detail if anyone is interested.

6) **Use the feedforward and feedback inhibition project to test whether a balance between excitation and inhibition affects information coding in a network performing perceptual discrimination.**Perceptual discrimination can be explored by varying the overlap between different input patterns and asking a network to perform pattern separation. For a given layer size and proportion overlap, how many patterns can a network discriminate, and how does excitation-inhibitory balance affect this ability?

7) **Simulate the effects of deep brain stimulation (DBS) on Parkinson’s Disease.** Parkinson’s disease is marked by a dramatic increase in the oscillatory pattern of the subthalamic nucleus (STN), thought to be the basis of tremor. The STN is also a common target for DBS as a treatment for Parkinson’s disease.

Use the basal ganglia model to simulate dopamine depletion in Parkinson’s. Explore the effect of varying the strength of projections between STN and GPe, which form a negative feedback loop that can be unstable and lead to oscillations. Simulate DBS in the STN and examine its effects on STN oscillations and behavior.

8) **Simulate the effects of sleep on episodic memory consolidation**. REM sleep is important in memory consolidation, a process during which memory is actually improved. One theory of how this occurs is though oscillations of inhibition that have the effect of strengthening weak memories (Norman, Newman & Perotte, *Neural Networks*, 2005). Simulate these oscillations in a cortical multi-layer model and examine the effects on memory interference.

10) **Amnesia and stroke**. Damage to the hippocampus and the medial temporal lobe from stroke can cause both anterograde amnesia (the loss of the ability to form new memories) and retrograde amnesia (the loss of previous memories). Simulate stroke damage to hippocampus and dissociate the effects of the two forms of amnesia.

11)  **Simulate epilepsy (seizures) related to dysregulated inhibition** and attempt to remediate this by other compensatory treatments (e.g. brain stimulation, neurodulation).

12) **Specialized processing of faces in the object recognition model.** The fusiform face area is a region of visual cortex that is preferentially active for faces. Using face-like stimuli determine if there are properties of a visual model that make it more or less adequate at discriminating faces.

13) **Simulate schizophrenia in a PFC-BG network** by changing dopamine levels and relate their effects to abnormal gating of working memory.

14) **Build a network model that does simple arithmetic (addition, subtraction).**

15) **Build a model that can regulate its learning rate as a function of its own uncertainty about the task contingencies** (for an example of this in the basal ganglia, see Franklin & Frank 2015, *eLife*, but one can attempt this in a more generic cortical network).

16) **Explore object recognition performance in a larger scale model of the visual system (computationally intensive; but models available)**

17) **Simulate higher order sequential dependencies or learning of context sensitive and/or context-free grammars in a PFC-BG working memory model; compare to SRN or LSTM (advanced).**

18) **Simulate motor adaptation effects in the cerebellum using a force field.** (can build off a prior project and the cerebellum model from the text).

19) **Explore how a model can perform 3D depth discrimination.**

20) **Compare activation-based accounts of working memory to those suggesting memory is encoded “silently” in a neural network (e.g. Stokes et al., 2013, *Neuron*; Rose et al., 2016, *Science*).**