CLAIMS

1. A computer implemented method for modeling brain function, the method comprising:

a) receiving functional neuroimaging data representing neural activity in one or more regions of interest in a brain of a subject;

b) receiving experimental electrophysiology data representing one or more neurons in said one or more regions of interest in the brain of the subject;

c) fitting functional neuroimaging data of the neural activity to a dynamic causal model (DCM);

d) calculating neural inter-regional and intra-regional connectivity strength estimates from the DCM;

e) generating a biophysics model that simulates synthetic electrophysiology data using the inter-regional and intra-regional connectivity strength estimates;

f) comparing the synthetic electrophysiology data to the experimental electrophysiology data; and

g) adjusting the biophysical model iteratively until model convergence is reached with the experimental electrophysiology data.

2. The method of claim 1, wherein the functional neuroimaging data comprises functional magnetic resonance imaging (fMRI) data, positron emission tomography (PET) data, functional near-infrared spectroscopy (fNIRS) data, single-photon emission computed tomography (SPECT) data, or functional ultrasound imaging (fUS) data.

3. The method of claim 2, wherein the fMRI data includes blood oxygen-level dependent (BOLD) signals.

4. The method of any one of claims 1 to 3, wherein the experimental electrophysiology data comprises electroencephalography (EEG) data, magnetoencephalography (MEG) data, or patch-clamping data.

5. The method of claim 1, wherein the functional neuroimaging data is optogenetic fMRI (ofMRI) data.

6. The method of any one of claims 1 to 5, wherein said one or more regions of interest are in cerebrum, cerebellum, or brainstem regions of the brain.

7. The method of claim 6, wherein said one or more regions of interest are in basal ganglia, striatum, medulla, pons, hypothalamus, thalamus, superior colliculus, cerebral cortex, neocortex, allocortex, hippocampus, or olfactory bulb regions of the brain.

8. The method of claim 7, wherein said one or more regions of interest are in frontal lobe, temporal lobe, parietal lobe, or occipital lobe regions of the brain.

9. The method of claim 7, wherein said one or more regions of interest are in caudate-putamen, external globus pallidus, internal globus pallidus, subthalamic nucleus, substantia nigra, thalamus, or motor cortex regions of the brain.

10. The method of any one of claims 1 to 9, wherein the one or more neurons are unipolar neurons, bipolar neurons, multipolar neurons, Golgi I neurons, Golgi II neurons, anaxonic neurons, pseudounipolar neurons, interneurons, motor neurons, sensory neurons, afferent neurons, efferent neurons, cholinergic neurons, GABAergic neurons, glutamatergic neurons, dopaminergic neurons, serotonergic neurons, histaminergic neurons, Purkinje cells, spiny projection neurons, Renshaw cells, or granule cells, or a combination thereof.

11. The method of any one of claims 1 to 5, further comprising receiving optical imaging data or multiphoton microscopy data representing the one or more regions of interest in the brain of the subject.

12. The method of any one of claims 1 to 11, wherein the subject has a neurological disease or disorder.

13. The method of claim 12, wherein the neurological disease or disorder is Parkinson’s disease, epilepsy, or Alzheimer’s disease.

14. The method of claim 12 or 13, further comprising detecting a change in brain function in the subject compared to brain function of a control subject based on said modeling brain function.

15. The method of any one of claims 12 to 14, further comprising identifying a neural circuit involved in pathological changes associated with the neurological disease or disorder.

16. The method of any one of claims 12 to 14, further comprising detecting a change in brain function in the subject based on data received from the subject after administering a treatment for the neurological disease or disorder compared to data indicating brain function of the subject received before the treatment based on said modeling brain function of the subject before and after administering the treatment.

17. The method of any one of claims 1 to 16, wherein the DCM is classical DCM, stochastic DCM, spectral DCM, or dynamic effective connectivity DCM.

18. The method of any one of claims 1 to 17, wherein the functional neuroimaging data or experimental electrophysiology data was acquired while the subject is in a resting state.

19. The method of any one of claims 1 to 17, wherein the functional neuroimaging data or experimental electrophysiology data was acquired while the subject is performing a task or responding to a stimulus.

20. The method of claim 19, further comprising identifying a neural circuit involved in performing the task or responding to the stimulus based on the functional neuroimaging data or experimental electrophysiology data.

21. A computer implemented method for modeling brain function, the computer performing steps comprising:

a) receiving functional neuroimaging data and experimental electrophysiology data for one or more brain regions of interest of a subject;
b) fitting the functional neuroimaging data to a dynamic causal model;

c) calculating neural inter-regional and intra-regional connectivity strength estimates from the dynamic causal model;
d) generating a biophysics model that simulates synthetic electrophysiology data from the inter-regional and intra-regional connectivity strength estimates;
e) comparing the synthetic electrophysiology data to the experimental electrophysiology data;
f) adjusting the biophysical model iteratively until model convergence is reached with the experimental electrophysiology data; and
g) displaying information regarding the modeling of brain function.

22. The computer implemented method of claim 21, wherein the functional neuroimaging data comprises functional magnetic resonance imaging (fMRI) data, positron emission tomography (PET) data, functional near-infrared spectroscopy (fNIRS) data, single-photon emission computed tomography (SPECT) data, or functional ultrasound imaging (fUS) data.

23. The computer implemented method of claim 21 or 22, wherein the experimental electrophysiology data comprises electroencephalography (EEG) data, magnetoencephalography (MEG) data, or patch-clamping data.

24. The computer implemented method of any one of claims 21 to 23, wherein the subject has a neurological disease or disorder.

25. The computer implemented method of claim 24, wherein said displaying information comprises listing one or more neural circuits involved in pathological changes associated with the neurological disease or disorder.

26. The computer implemented method of any one of claims 21 to 25, wherein the functional neuroimaging data and the experimental electrophysiology data are acquired while the subject is performing a task or responding to a stimulus, wherein said displaying information comprises listing one or more neural circuits involved in performing the task or responding to the stimulus.

27. A system for modeling brain function using the computer implemented method of any one of claims 21 to 26, the system comprising:

a) a storage component for storing data, wherein the storage component has instructions for modeling brain function based on analysis of the functional neuroimaging data and experimental electrophysiology data stored therein;

b) a computer processor for processing the functional neuroimaging data and experimental electrophysiology data using one or more algorithms, wherein the computer processor is coupled to the storage component and configured to execute the instructions stored in the storage component in order to receive the inputted functional neuroimaging data and experimental electrophysiology data and analyze the data according to the computer implemented method of any one of claims 21 to 26; and

c) a display component for displaying the information regarding the modeling of brain function.

28. A non-transitory computer-readable medium comprising program instructions that, when executed by a processor in a computer, causes the processor to perform the method of any one of claims 21 to 26.

29. A kit comprising the non-transitory computer-readable medium of claim 28 and instructions for modeling brain function from functional neuroimaging data and experimental electrophysiology data.