

# **Concussion as a complex system: Building a system dynamics model of mild traumatic brain injury**

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# Concussion is common

- In the United States, an estimated 1.7 million people suffer a traumatic brain injury every year (Faul et al. 2010).
  - 70-90% of these cases are mild TBI, or concussion (Cassidy et al. 2004).
- Concussion is vastly underreported; one study found that at least 88% of cases might go unrecognized (Delaney et al. 2005). In fact, a recent NPR poll found that 1 in 4 Americans report having suffered a concussion.
- Has become a known issue in athletic and military arenas; sufferers are also the elderly, motor vehicle accident victims, and domestic violence survivors, among others.

# Concussion is poorly understood

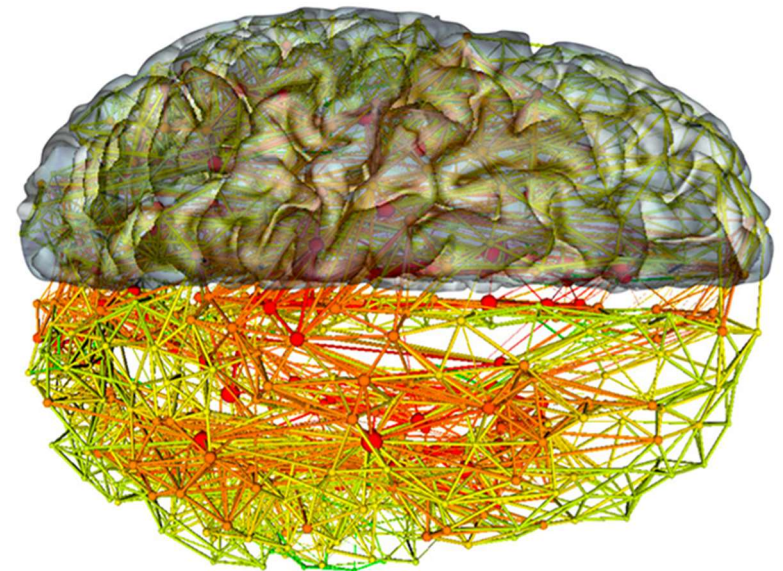
- No single definition of concussion is accepted across disciplines, though several different definitions are available (Comper et al. 2005; Hawryluk & Manley 2015).
  - Complicates clinical trials
- Recovery trajectories are unpredictable: some people recover quickly and others have lasting deficits.
  - Biochemical and cellular changes occur days and even years after a traumatic event (Kovac, 2016)
- There are still no FDA approved treatments or therapies for TBI (Hack, 2016)
- Inadequate classification system for TBI
  - Are concussions on the same spectrum as coma?
  - Does type of concussion matter? Blast vs. impact, etc.
- No shared mental model of pathophysiology

# Concussion is complex

- Traumatic brain injury has been called  
**“the most complicated disease of the most complex organ of the body”** (Marklund and Hillered 2011).
- The human brain has:
  - Billions of neurons with trillions of connections
  - Billions of nonneuronal cells, too:
    - Neuroglia & blood vasculature



Image source: visionforlife.com



(Image: Martijn van den Heuvel, Journal of Neuroscience.)

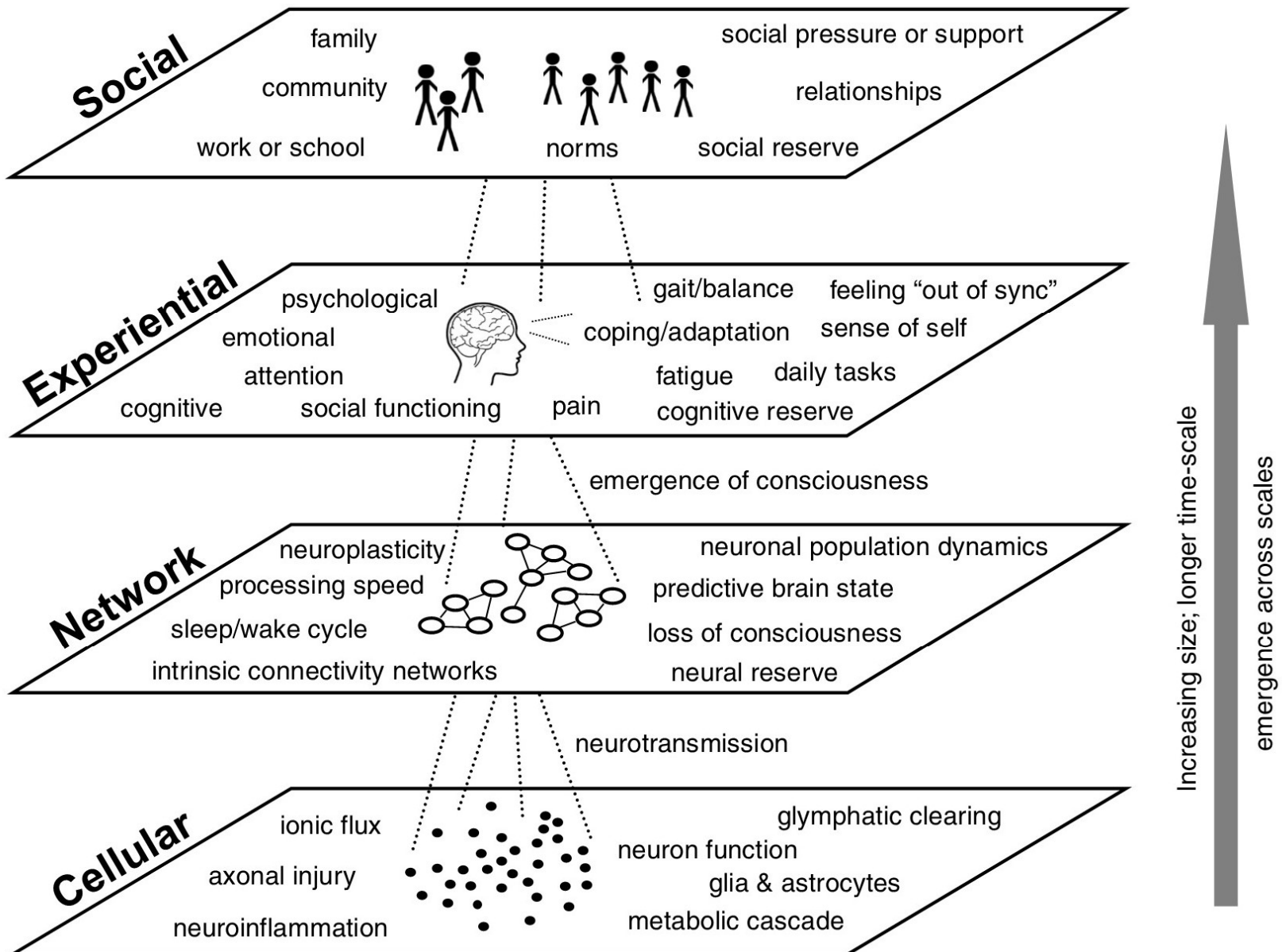
# Concussion is complex

- Heterogeneity
  - In individual brains, modes of injury, length of recovery, and signs, symptoms, and deficits
- Dynamic: factors throughout recovery period affect outcomes
- Involves many stakeholders, and subfields:
  - In medicine: neurotrauma, neurosurgery, neurology, psychiatry, sports medicine, rehabilitation, speech therapy, neuroscience, etc.
  - In research: animal, human, post-mortem; molecular, cellular, systems, computational; academia, sports, military, and more

# Taking a systems approach

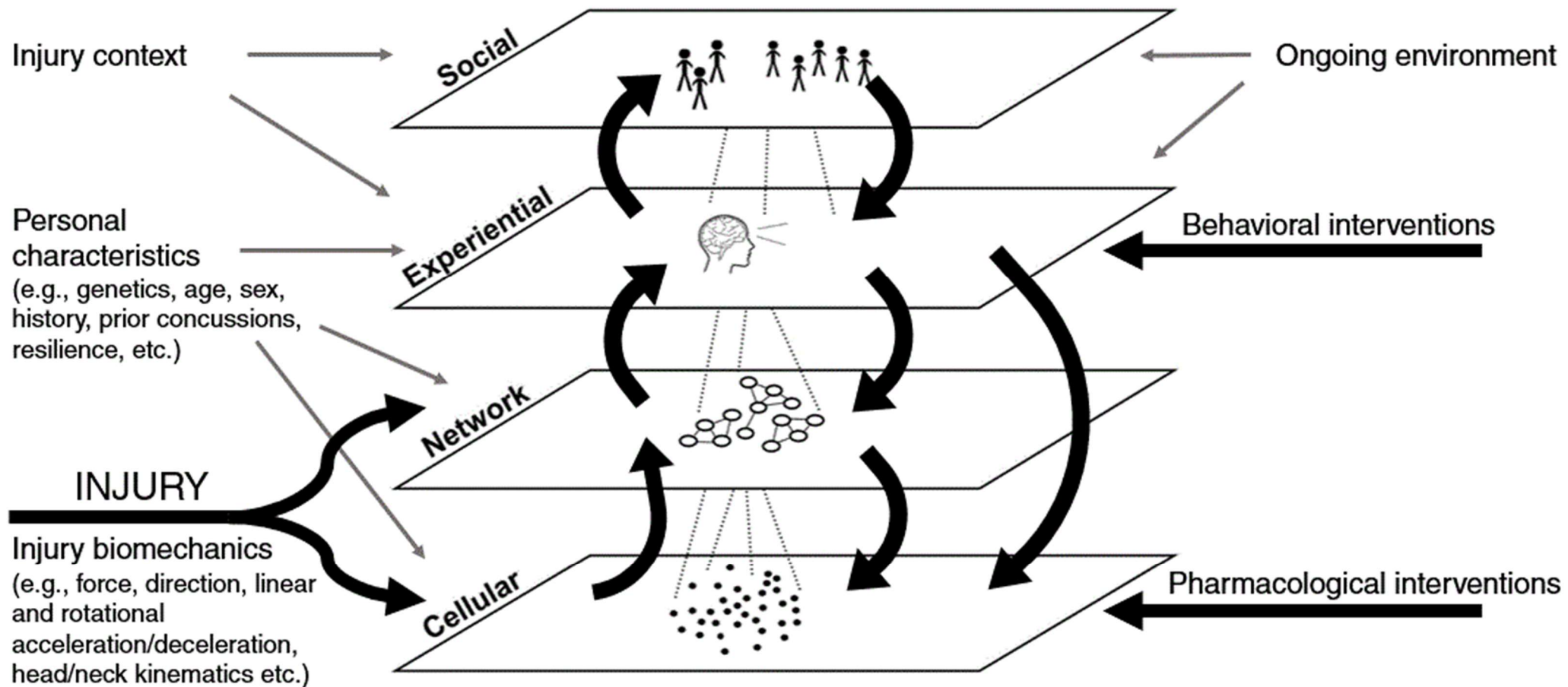
- TBI researchers approached us looking for a new method. Project led by systems scientists in collaboration with large team of investigators from many subfields of medicine.
- Methods: extensive review of relevant literature; interviews with key researchers, clinicians, and athletic trainers. Facilitated focus group with young athletes experiencing prolonged recovery.
- Created two conceptual models for concussion: multi-scale conceptual framework and causal-loop diagram (CLD)
- Drafted conceptual models, collected information, and reviewed model with experts in iterative process

# Multi-scale framework for concussion



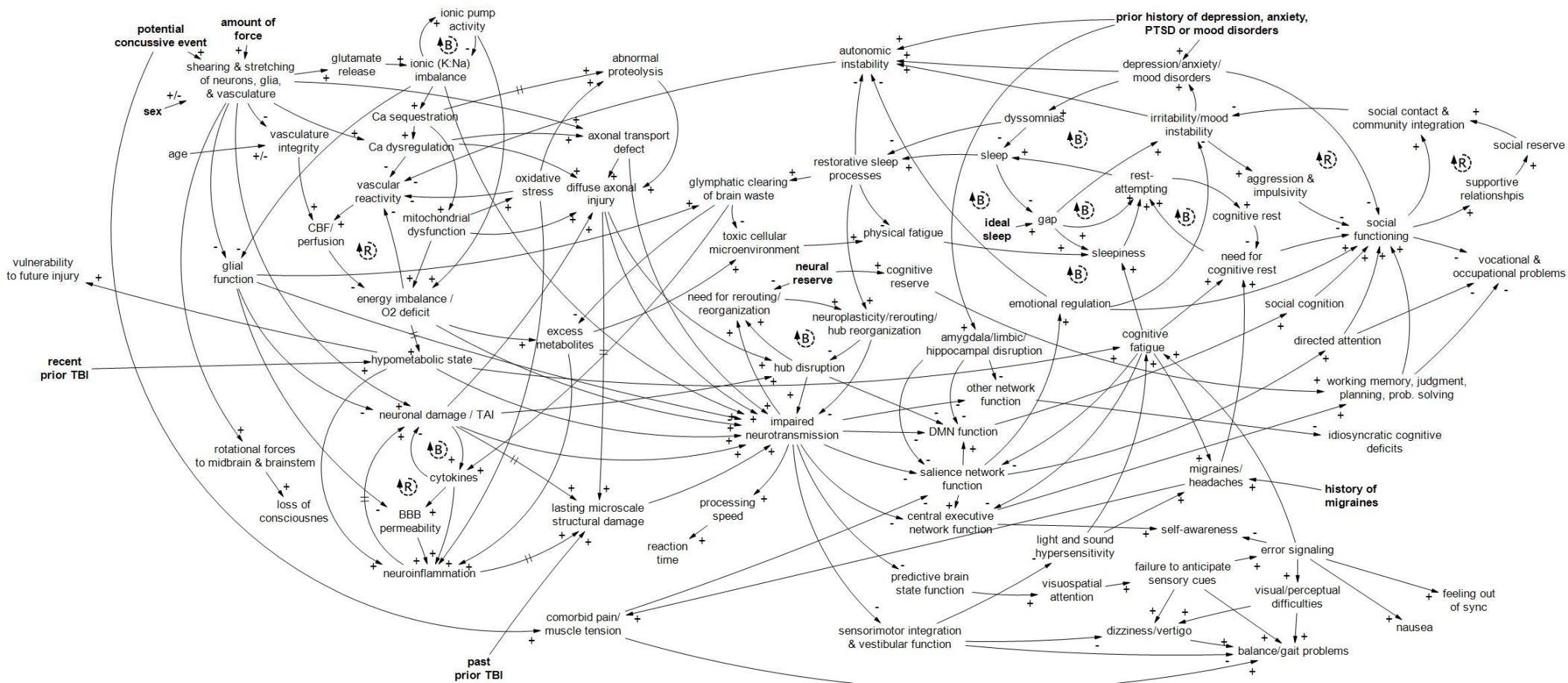


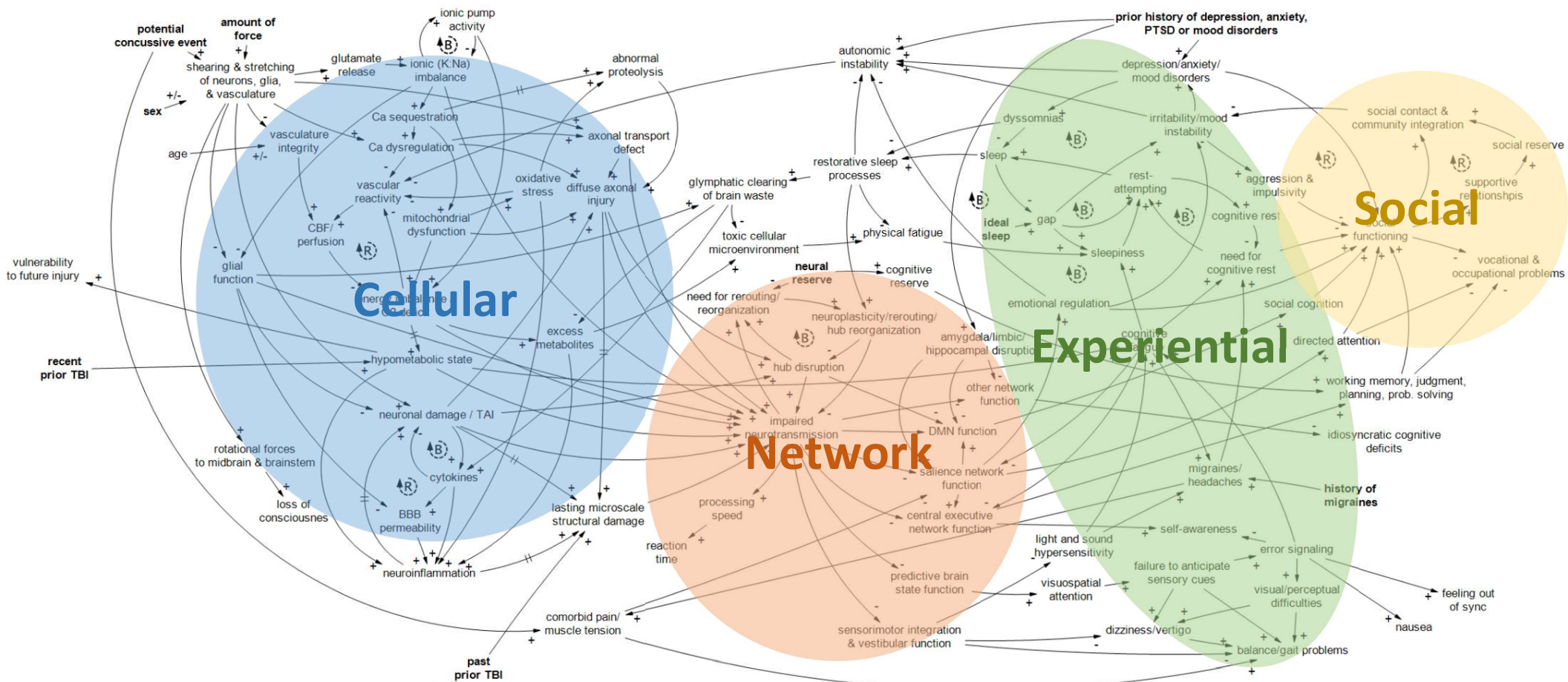
# Exogenous drivers and cross-scale feedback in the multi-scale framework





# Causal-loop diagram of concussion





# Next steps

- In process of submitting first conceptual model for publication
- Complete CLD with collaborators this summer, and prepare for publication
- Create an operational system dynamics model, with the goal of generating individual recovery trajectories to aid understanding and classification