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Coordinated encoding between cell types in the retina: insights from the theory of phase transitions[1]

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In this talk I will describe how the emergence of some types of neurons in the brain can be quantitatively described by the theory of transitions between different phases of matter. The two key parameters that control the separation of neurons into subclasses are the mean and standard deviation of noise levels among neurons in the population. The mean noise level plays the role of temperature in the classic theory of phase transitions, whereas the standard deviation is equivalent to pressure, in the case of liquid-gas transitions, or to magnetic field for magnetic transitions. Our results account for properties of two recently discovered types of salamander OFF retinal ganglion cells, as well as the absence of multiple types of ON cells. We further show that, across visual stimulus contrasts, retinal circuits continued to operate near the critical point whose quantitative characteristics matched those expected near a liquid-gas critical point and described by the nearest-neighbor Ising model in three dimensions. Because the retina needs to operate under changing stimulus conditions, the observed parameters of cell types corresponded to metastable states in the region between the spinodal line and the line describing maximally informative solutions. Such properties of neural circuits can maximize information transmission in a given environment while retaining the ability to quickly adapt to a new environment.

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