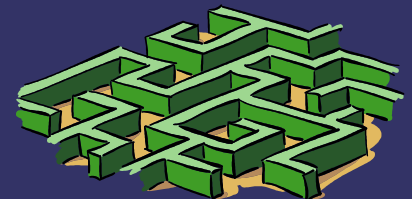


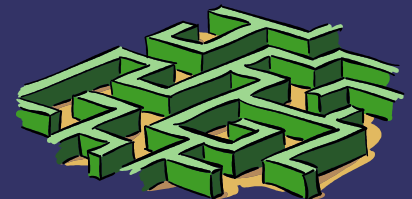
# *The physics of downward causation*

A look at a paper by  
Paul Davies



# *Reductionism*

- ⇒ Is good
- ⇒ “the arrows of explanation point downward”  
- Steven Weinberg, 1992
- ⇒ *...we frequently account for a phenomenon by appealing to the properties of the next level down.*
- ⇒ *merely a fruitful methodology?*
- ⇒ *whole story?*



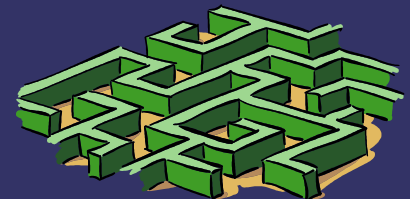
# *Anti-reductionists deny*

- ➔ *A living cell is nothing but a collection of atoms*
- ➔ *A human being is nothing but a collection of cells*
- ➔ *Fallacy of the “nothing-buttery”*
- ➔ *[Anti-reductionists] are impressed by the powerful organizational abilities of complex multi-component systems acting collectively, which sometimes lead to novel and surprising forms of behavior.*



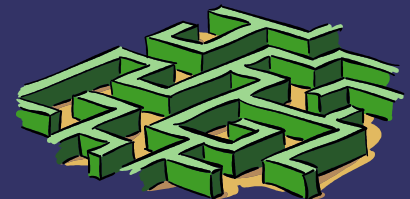
# *Reductive accounts can be adequate*

- ⇒ The environment must be included in the system
  
- ⇒ Hurricanes
  - Red spot of Jupiter
  
- ⇒ Quantum superposition
  - decoherence

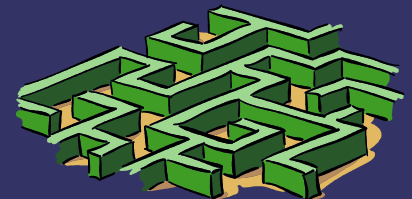
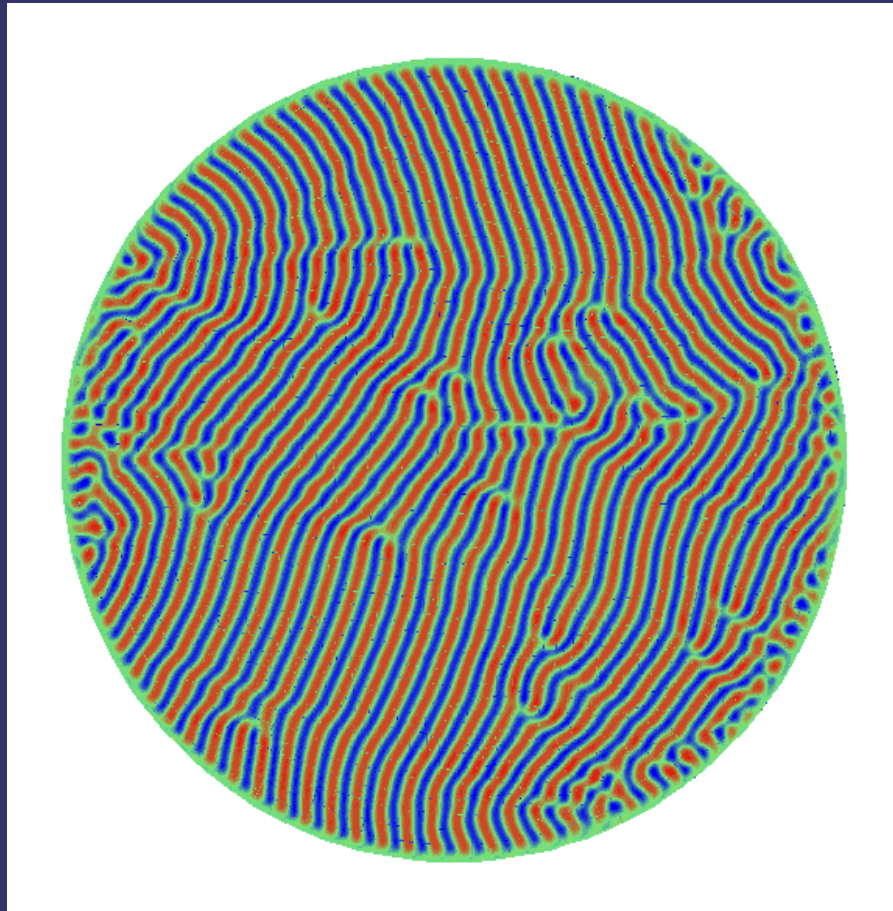


# *Emergent Phenomenon*

- ➔ Ever the case that an emergent phenomenon cannot be given a satisfactory reductive account?
- ➔ Benard instability: fluids spontaneously form convection cells, the molecules organize themselves into an elaborate and orderly pattern of flow

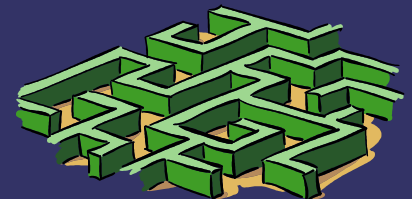


# *Rayleigh-Benard convection cell*



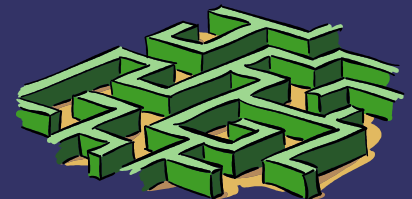
# *Bernard Instability*

- ⇒ Individual molecules push and pull on their near neighbors
- ⇒ Hints at a global choreographer
- ⇒ Emergent daemon marshaling the molecules into a coherent, cooperative dance
- ⇒ What causes a given water molecule to follow a particular path?
  - Need to appeal to a *global* pattern to provide a complete answer



# *The Full Account*

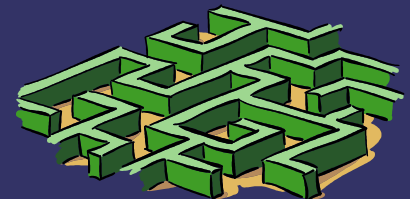
- ⇒ We need two sorts of forces
  - Near-neighbor forces
  - Global forces
- ⇒ A molecule's motion is caused by the near-neighbors in the context of their own global, systematic motion
- ⇒ Need:
  - Local forces
  - Contextual information of global circumstances



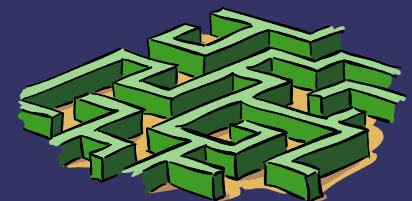
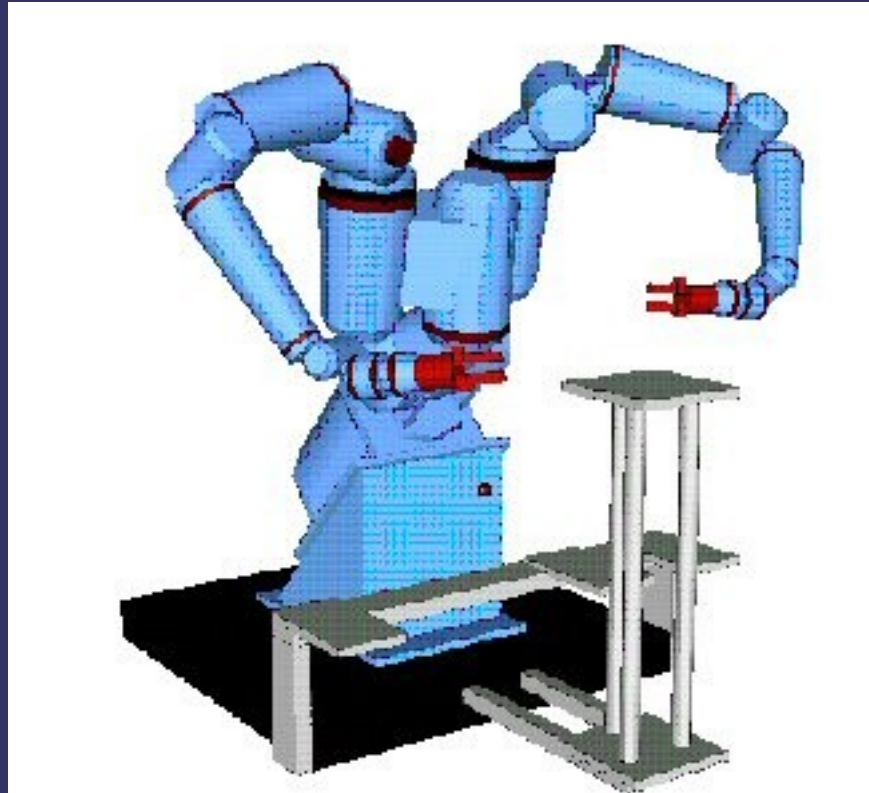
# *Downward Causation*

## ⇒ Causality

- Operates locally, via a *local field*
- The force acting on a particle at a point is determined by the nature of the field at that point
- An electron may accelerate as a result of an electric field, and the magnitude of the force causing the acceleration is given by the intensity of the field at the point
- How can a whole act causatively on its parts, if all interactions are local?

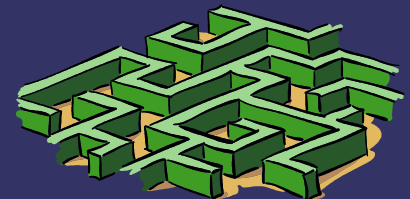


# *Software-Hardware Feedback*



# *Higher Levels acting on Lower?*

Another example is hardware versus software in computing. Consider the statement: ‘The program is designed to find the smallest prime number greater than one trillion and print out the answer.’ In this case the higher-level concept ‘program’ appears to call the shots over what an electronic gizmo and printer and paper does. Many examples may be found in the realm of human affairs, such as economics. Pronouncements such as, ‘stock market volatility made investors nervous’ conveys the impression that the higher-level entity ‘the stock market’ in part determines how individual agents behave.



# *Which is more fundamental?*

⇒ Local laws

- Quantum interactions

⇒ Global laws

- Conservation

Both at the same time?

