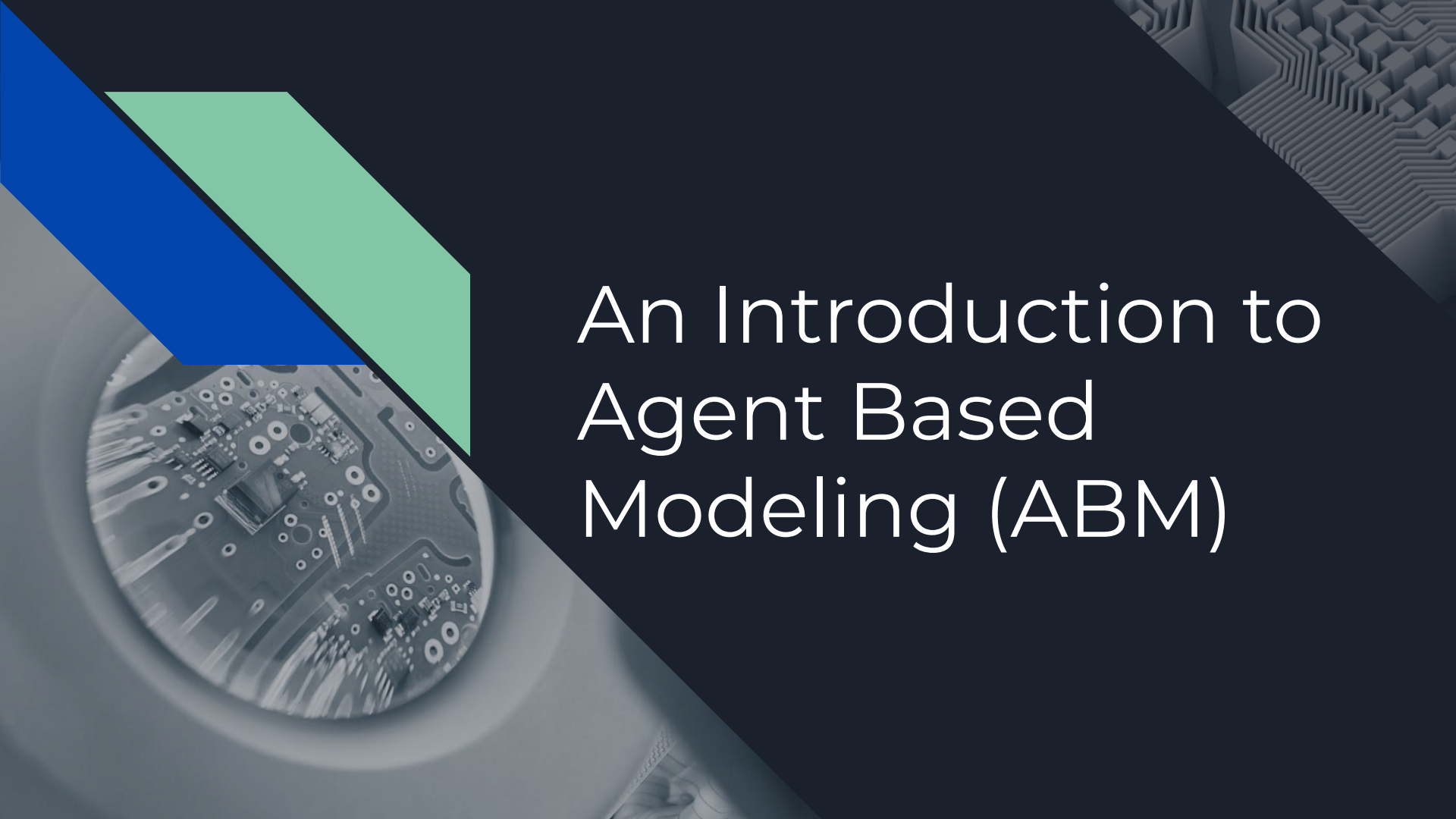


An Introduction to Agent Based Modeling (ABM)

What is Agent Based Modeling??

ABM is a methodology that is used to build formal models of real-world systems, where these systems are made up by *individual units*

- Atoms, cells, animals, humans, institutions...etc.

These *individual units* repeatedly interact among themselves and/or their environment

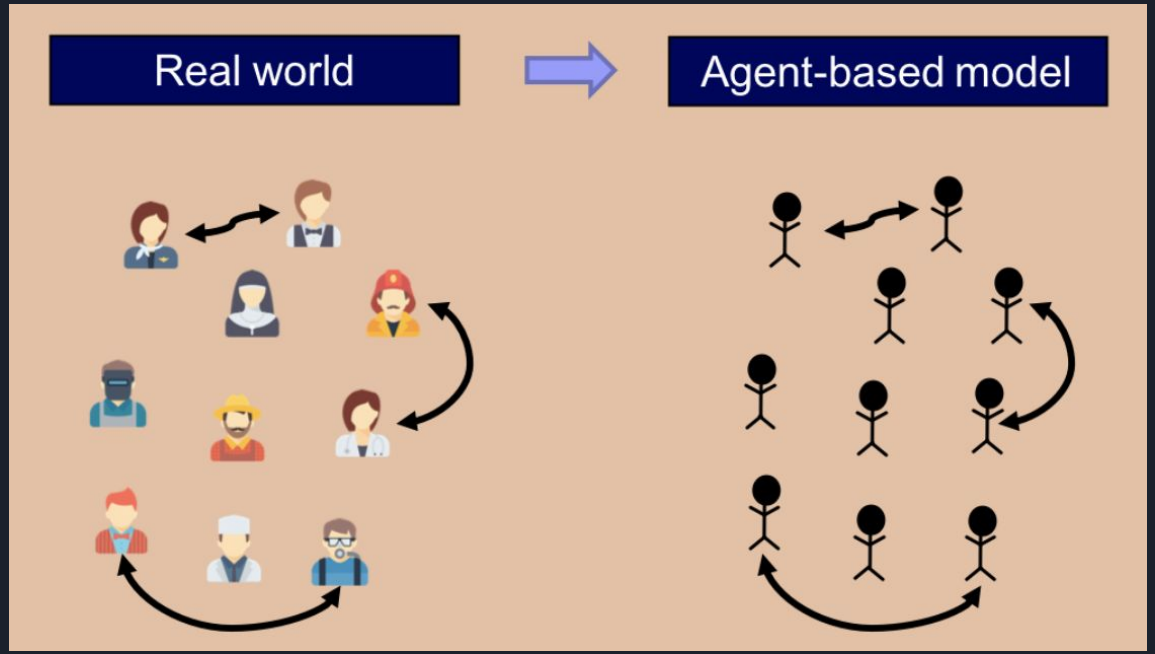
The *Essence* of ABM

So what makes Agent Based Modeling Different from other Formal Model Methodologies? I.E. equation based modeling.

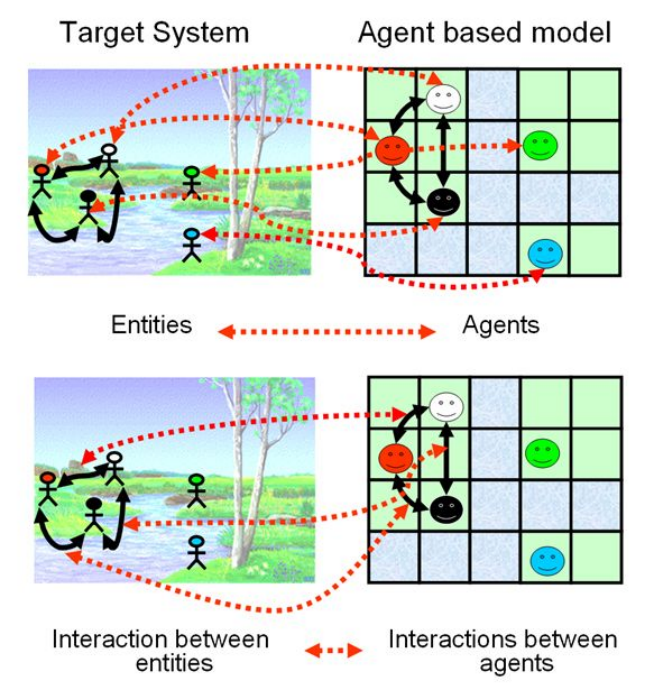
Well, the defining feature of the ABM ‘approach’ is that it establishes direct and explicit correspondence…

- Between the individual units in the target system to be modeled, and the parts of the model that represent these units (i.e.) the agents
- Between the interactions of individual units in the target system and the interactions of corresponding agents in the model

Understanding what I just said with a picture



Thus...



In ABM, the individuals units of the system and their repeated interactions are *explicitly* and *individually* represented in the model.

Beyond this...no further assumptions!

REMINDER - the system is what we're trying to model, the model is ABM.

Benefits of ABM

Flexibility - in principle, you can make your agent-based model as complex as you wish. Adding more complexity, however, comes at the cost of making it harder to analyze and understand

Captures Emergent Phenomena - emergent phenomena result from the interactions of individual entities. The whole is more than the sum of its parts because of the interactions between the parts. SEE PNAS

Provides a natural description of a system

Emergent Phenomena

- Emergent Phenomenon result from the interactions between individuals beings. By definition, they are greater than the sum of their parts because their essence is held in the interactions amongst them.
- Emergent phenomenon can have properties that are decoupled from the properties of the parts.
- ABM by its nature, is the canonical approach to modeling emergent phenomena.

When to use ABM for Emergent Phenomena

- Individual Behavior is nonlinear and can be characterized by
  - If-then rules
  - Nonlinear coupling
- Individual behavior exhibits memory, path-dependence, and hysteresis, non-markovian behavior, or temporal correlations, including learning and adaptation
- Agent interactions are heterogeneous and can generate network effects
- Average will not work

What is an agent?

Agents can be thought of as decision-makers in our model.

- Human, non-human, animals, institutions, firms, etc.

Agents have *individually-owned variables*, which describe their internal state (e.g. a strategy)

- They are able to conduct certain computations or tasks (i.e. run their instructions)
  - E.g. update their strategy
- Instructions are sometimes called decision rules, or rules of behavior
  - Most often imply some kind of interaction with the other agents or with the environment

Examples of individually-owned variables and instructions, respectively

- Examples of individually-owned variables
  - Strategy (a number)
  - Payoff (a number)
  - My-coplayers (set of agents with whom this agent players the game)
  - Color (color of this agent)
- Examples of instructions
  - To play (play a certain game with my-coplayers and set the payoff appropriately)
  - To update-strategy (revise strategy according to a certain revision protocol)
  - To update-color (set color according to strategy

A Canonical Example

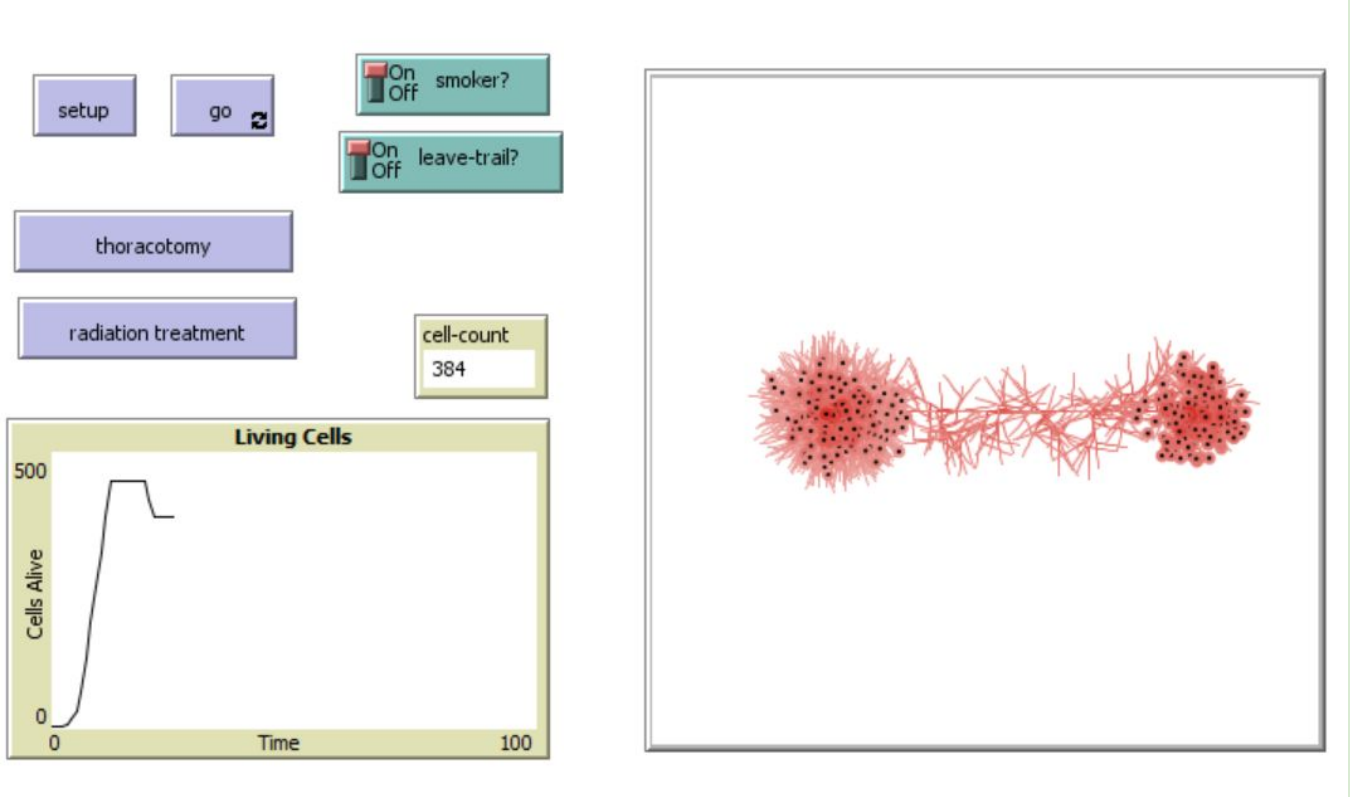
- 133 blue agents, 133 orange agents who live in a 2-dimension grid made up of 20x20 cells
- Agents initialize at a random location
- The ‘neighborhood’ of a cell is defined by the eight neighboring cells

- Agents may be happy or unhappy.
  - Happy if the proportion of other agents of its same color in its neighbourhood is greater than or equal to a certain threshold (a parameter of the model)
  - Otherwise, unhappy

A Canonical Example Continued

- Every iteration, one unhappy agent is randomly selected to move to a random empty cell in the lattice

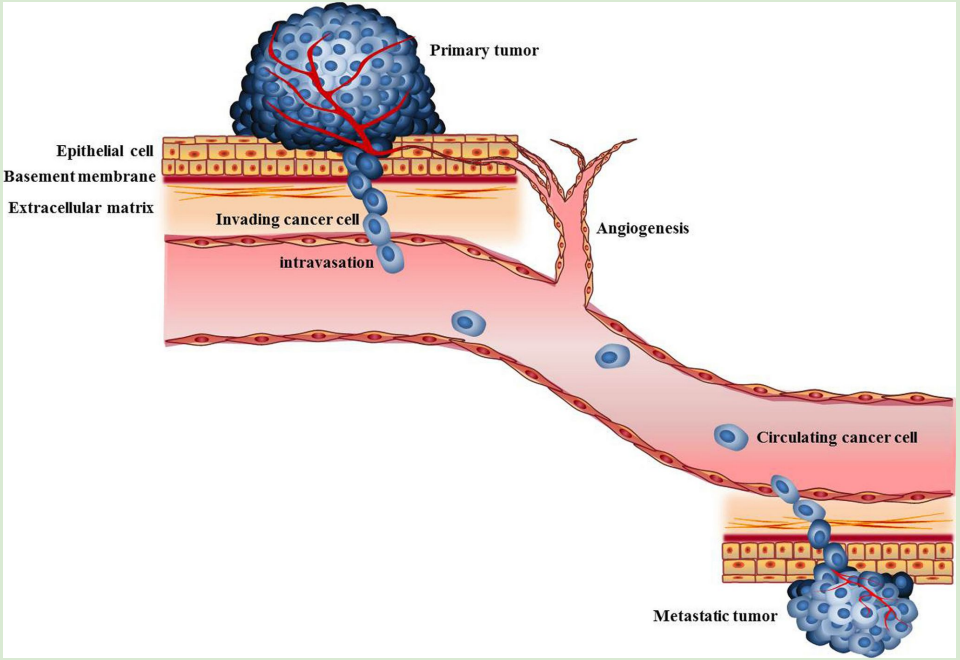
In Today's Workshop: Tumor Model



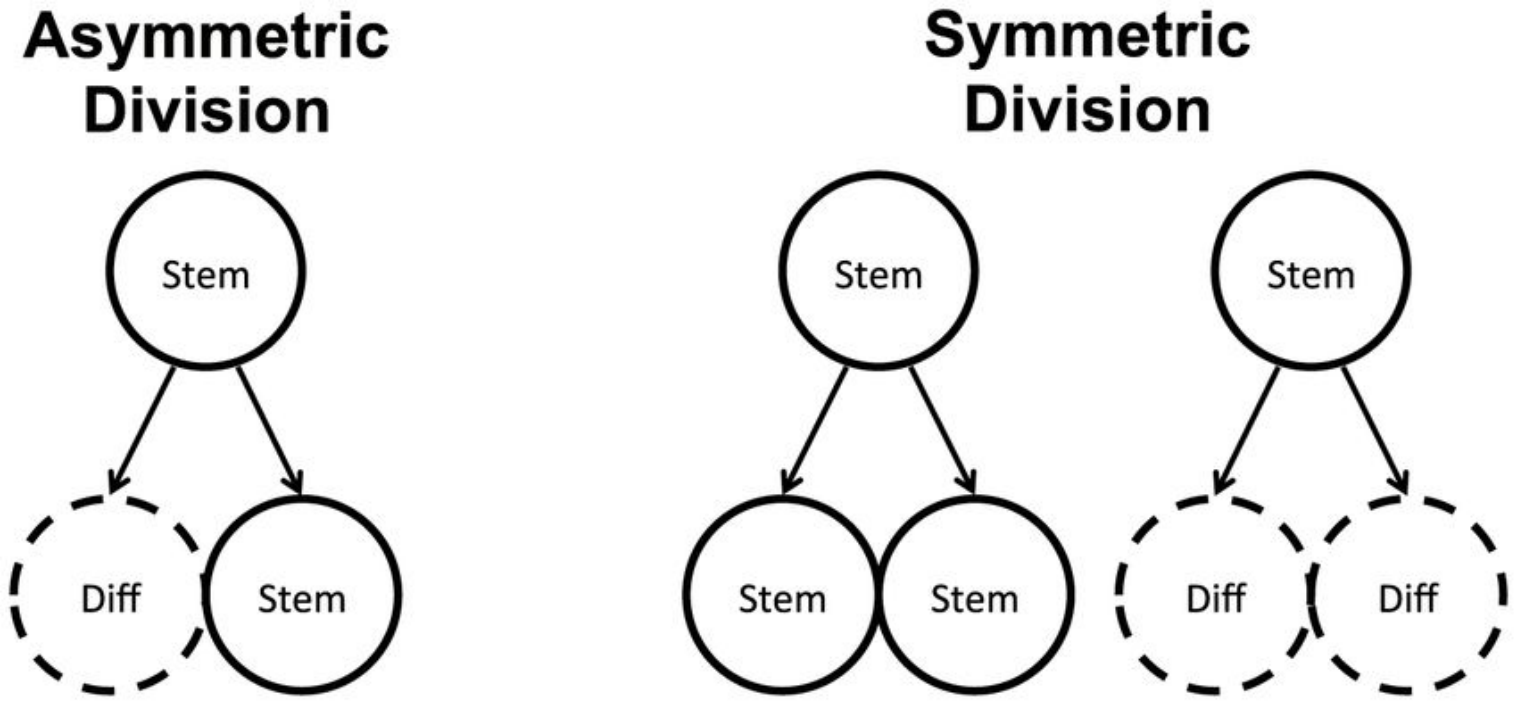
Stem Cells and Tumors

- Stem cells are cells with the potential to develop into many different types of cells in the body.

- Through accumulation of mutations over time, uncontrolled cell divisions in the stem cells can cause **cancer**.



Types of Stem Cell Divisions



Smoking and Lung Cancer

- Tobacco smoke contains at least 60 carcinogen chemicals.

- These chemicals cause mutations in cells that drive cancer genes to become active and lead to tumorigenesis.