The Ethical Dilemmas of Modeling Addiction In Public Health

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Why are Public Health models important?

- Allows us to predict the spread of communicable diseases, like Covid, etc.
    - Forecasting according to current disease transmission and recovery trends
    - Informed treatment and intervention planning based on predicted effectiveness
    - Emergency outbreak and contagion quarantine protocol implementation
- Influences legislation and public policy:
    - Includes funding and resource allocation for various social programs
    - Allows evaluation of effectiveness of interventional legislation and programs; tobacco taxes, increased third places, increase green spaces in urban environments,
- Can be used to identify environmental or societal risk factors that significantly increase the likelihood of contracting a disease or becoming an addict
- Can identify the causal relationship between specific risk factors and our ‘disease’
- Attempts to understand and capture patterns in the macroscopic behavior of a patient

What are the tiers of models?

Simplistic and Consequential Models:

- Probabilistic, purely observational models (Markov Chains, Decision Trees, etc.)
- SIR & SEIR models for communicable diseases

More complex:

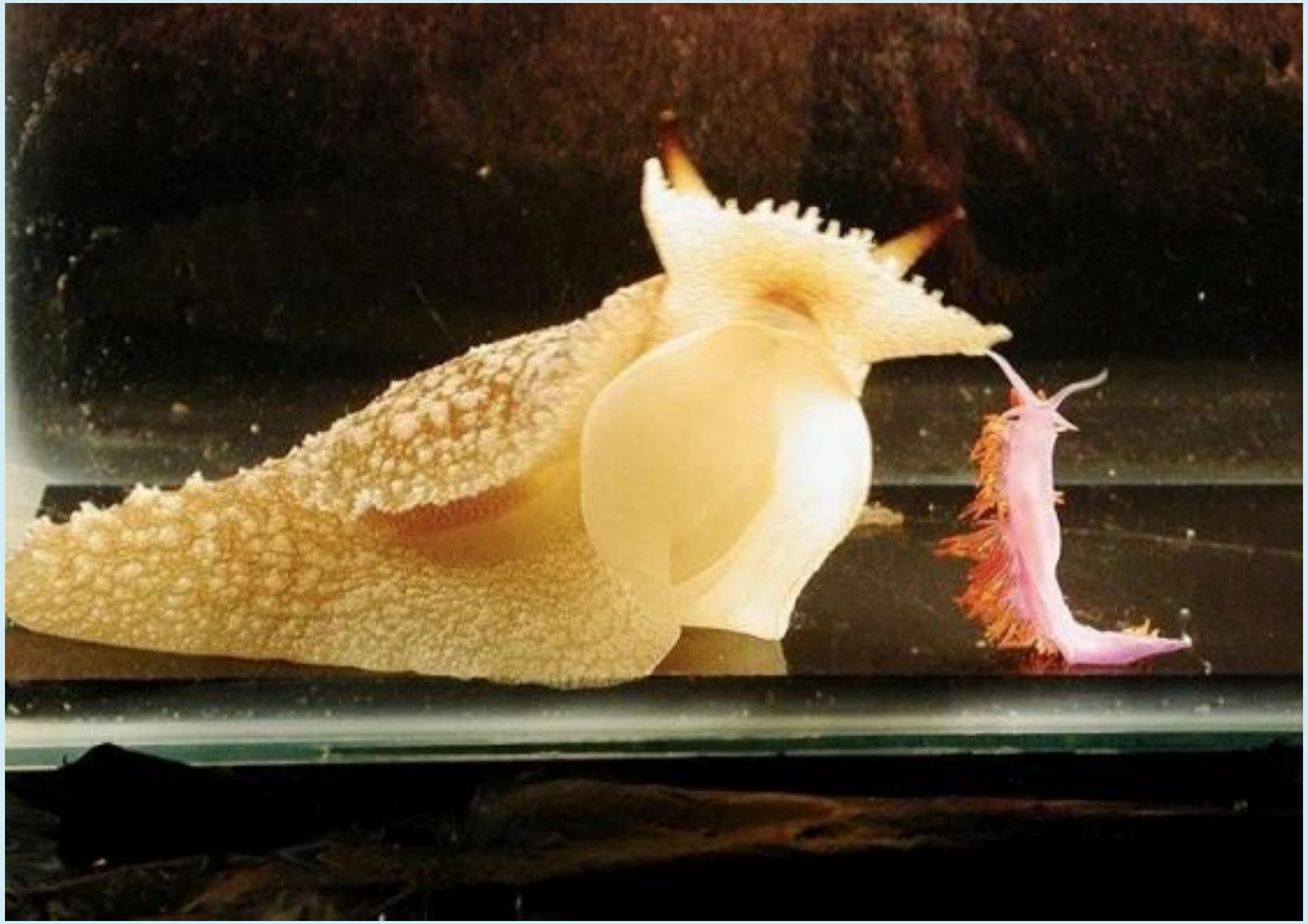
- Models that involve underlying neurochemistry and biological processes
- Models that account for simple, environmental and social factors
- Models that have non-deterministic variables (Hidden Markov Chains)

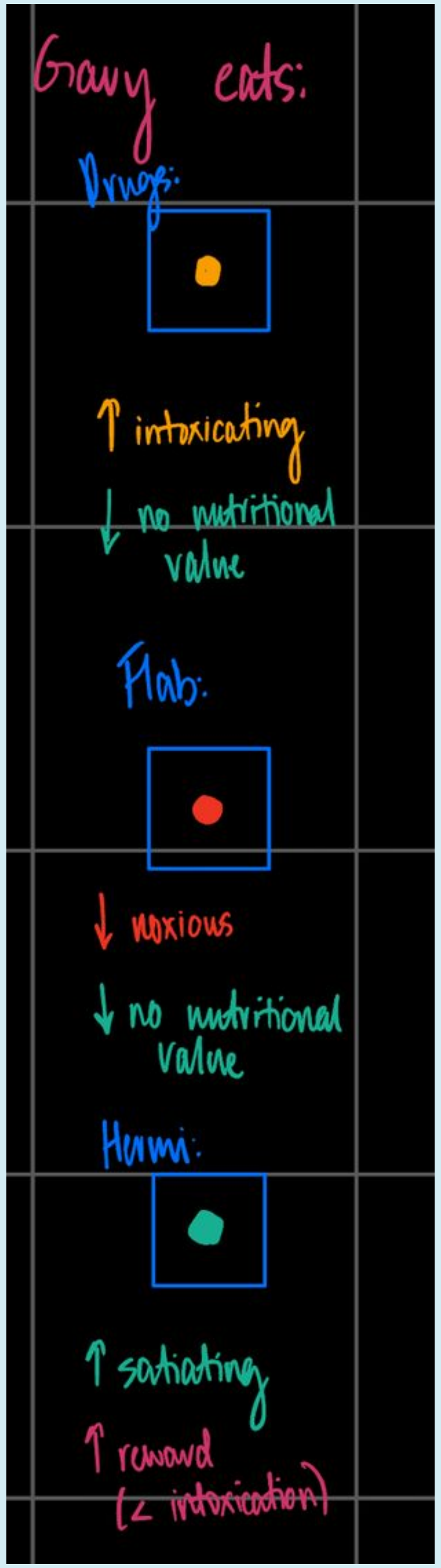
Most complex:

- Models that capture complex social interaction
- Models that realistically represent the potential consequences of healthcare
- Models that dynamically change in response to new stimulus (Learning, homeostatic capacity, nonlinear recall, memory, etc.)

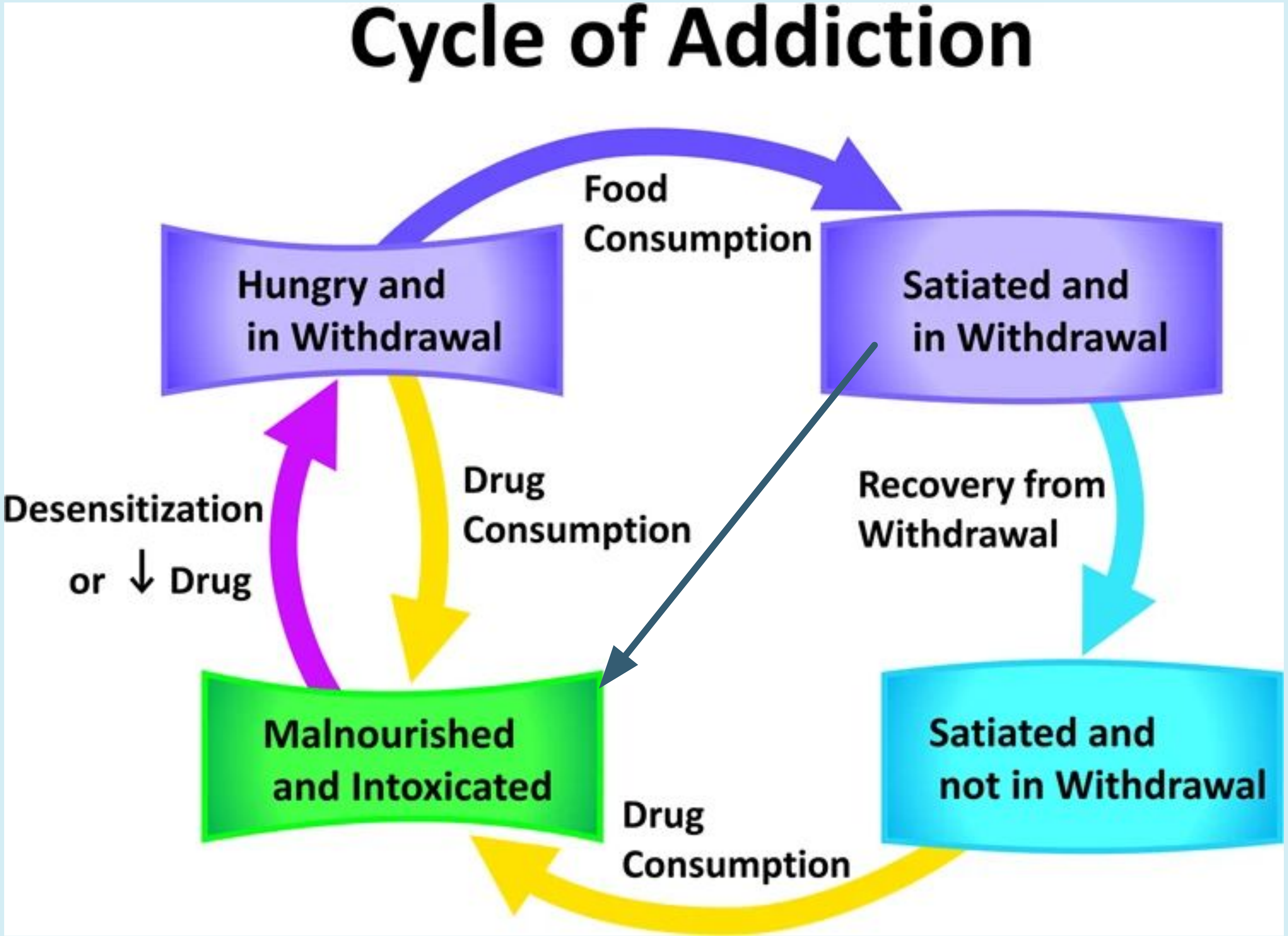
Motivating Example for Addiction Modeling

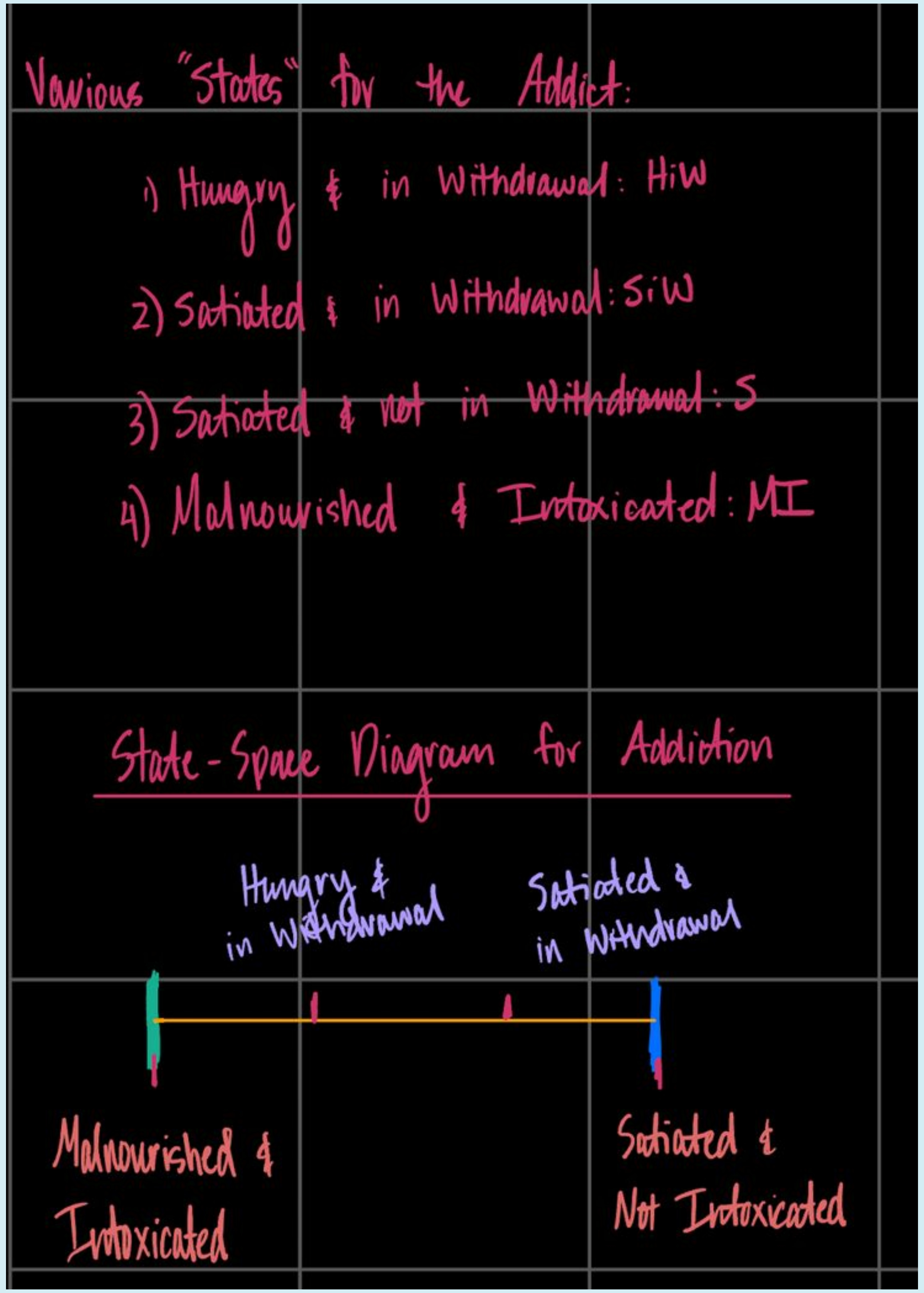
Gary & Fred





Simple Models - Markov Chains based on IUIC's Cyberslug Model





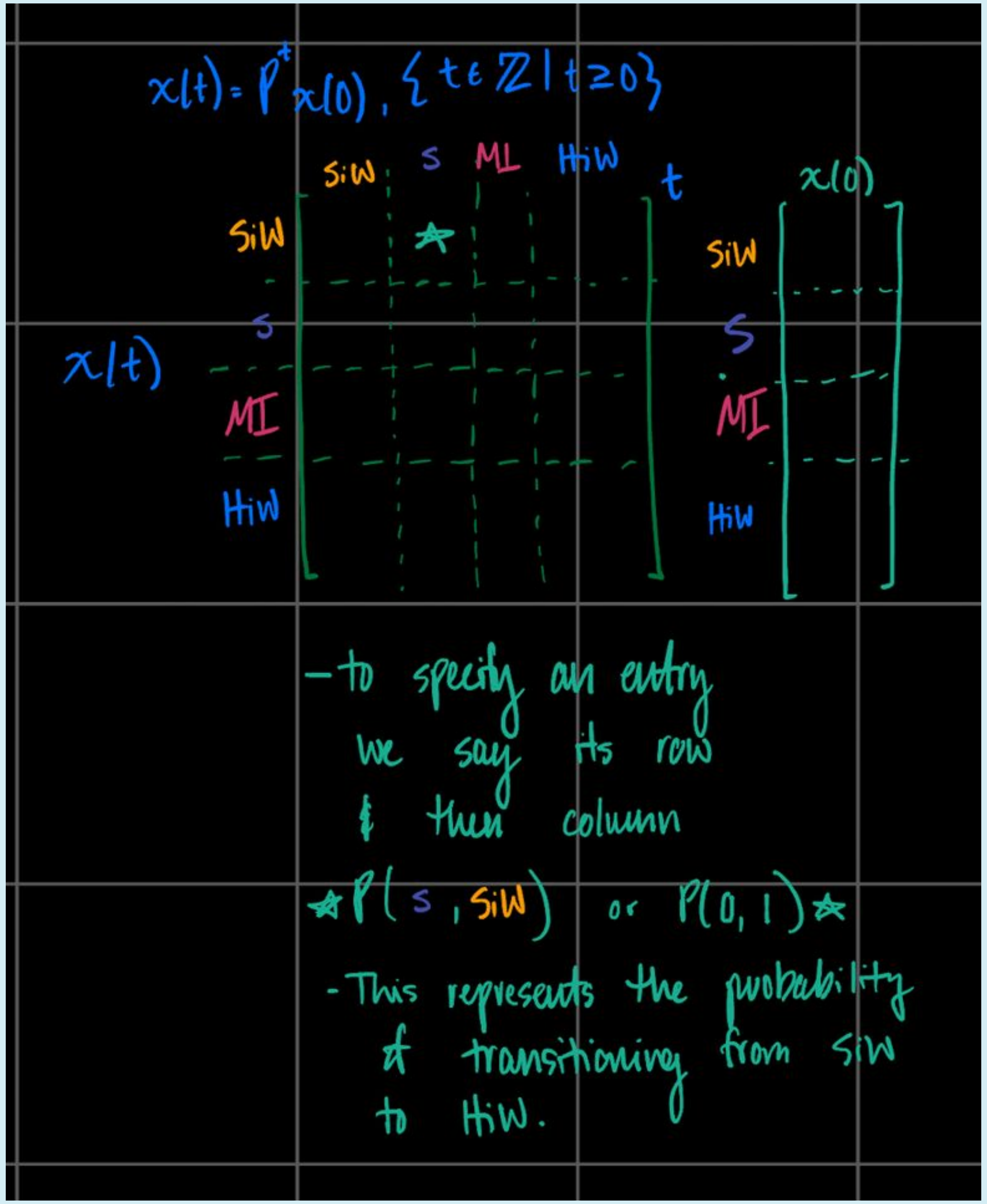
Markov Chains Continued

Probability Transition Matrix, P:

1. Represents the probability that an individual patient transitions from one state to any other state
2. Must be a stochastic matrix:
    a. Must be square, such that it has the same number of rows as it has columns
        i. It's dimensions are nrow by ncol
    b. Must contain real-valued entries over the interval [0,1]
        i. Each entry represents the probability of transitioning from one state to another
        ii. 0 := the transition from state icol to irow is impossible
        iii. 1 := the transition is guaranteed
    c. Each column must have a sum of exactly one

Markov Chains Continued

Let x(t) be a function that models the population of sea slugs @ time t, where t is a positive integer value. Let x(o) be the initial population of sea slugs as a column vector, with entries representing the amount of individuals in that state @ t=o. For every step, dt, every sea slug must eat.



Sample Markov Chain Problem

Our friend Gary has a really big family. He's excited for the holiday and he wants to be a hospitable host: he wants to know what he needs to prepare in order for everyone in his family to be included, but first he needs to know who's coming and what they'd like. Their initial population, including Gary, and transition probabilities are:

Total: 5000 sea slugs, including Gary, st:

1. SiW: 400 sea slugs, .05 to S, .3 to SiW
2. S: 4200 sea slugs, .15 to MI
3. MI: 250 sea slugs, .7 to HiW , .1 to SiW
4. HiW: 150 sea slugs, .7 to SiW

Find the population of Gary and his family five months in the future:

Sample Markov Problem:

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Conclusion from the result:

- 47% are currently involved in drugs
- 34% are hungry

$$x(t) = \begin{array}{c|cccc|} & SiW & S & MI & HiW \\ \hline SiW & .3 & 0 & .1 & .7 \\ S & .05 & .85 & 0 & 0 \\ MI & 0 & .15 & .2 & .3 \\ HiW & .65 & 0 & .7 & 0 \end{array}^{\,t} \begin{array}{c|c|} & x(0) \\ \hline SiW & 400 \\ S & 4200 \\ MI & 250 \\ HiW & 150 \end{array}, \quad t = 5 \text{ months}$$

$$x(5) = \begin{array}{c|cccc|} & SiW & S & MI & HiW \\ \hline SiW & .50 & .21 & .52 & .52 \\ S & .12 & .46 & .07 & .08 \\ MI & .17 & .20 & .18 & .18 \\ HiW & .21 & .13 & .23 & .22 \end{array} \begin{array}{c|c|} SiW & 400 \\ S & 4200 \\ MI & 250 \\ HiW & 150 \end{array}$$

$$x(5) = \begin{bmatrix} 1290 \\ 2010 \\ 980 \\ 720 \end{bmatrix} \begin{array}{l} \text{, satiated \& in withdrawal} \\ \text{, sober \& satiated} \\ \text{, malnourished \& intoxicated} \\ \text{, hungry \& in withdrawal} \end{array}$$

$\Sigma = 5000$

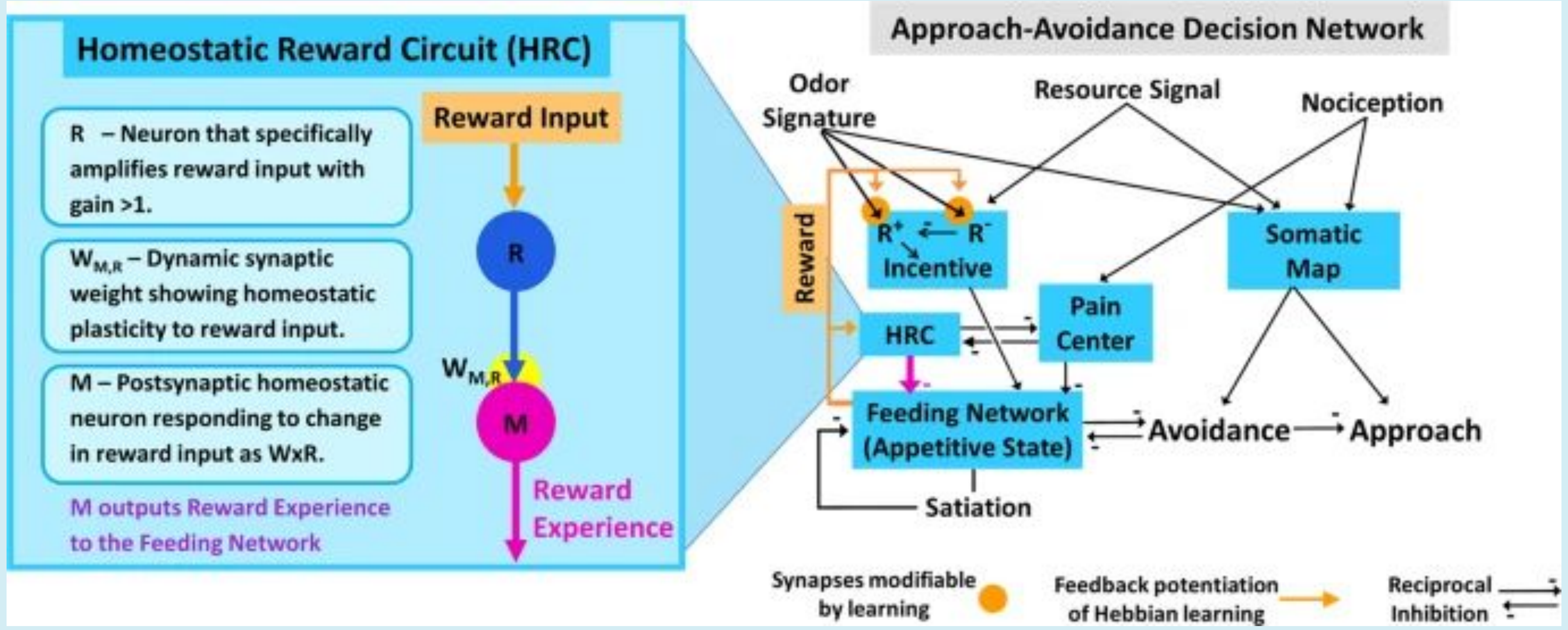
Real Markov Chain Problems

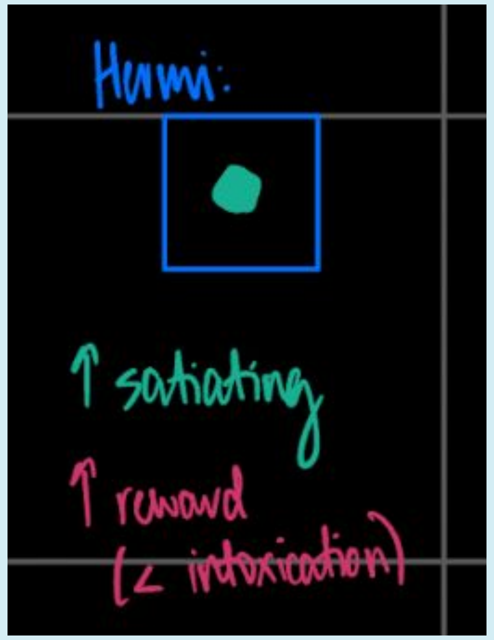
- Where are these percentages coming from?
- Where is the inclusion of healthcare services and their impact on recovery rate?
- What about the fact that some addicts may die? What about complete remission? There is no state for casualties of addiction.
- Why is everyone assumed to being predisposed to doing drugs? What about the individual and their specific values? Where do cognition and personality fit into this?
- What about risk factors? If Gary’s cousin’s parents are addicts, does that make Gary’s cousin more likely to be an addict?
- How are Gary and his family getting their drugs? Are they being constantly peddled to them? Are they aware of what the drugs are doing to them? What about capturing threats of paternalism?

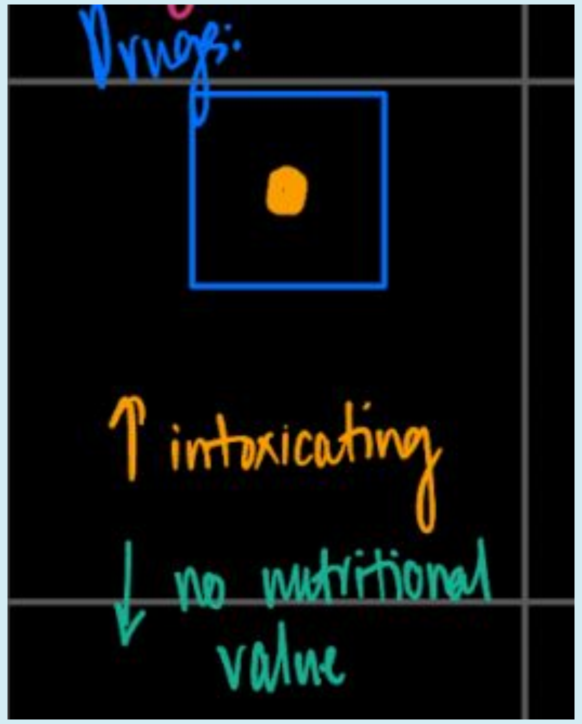
IUIC's ASIMOV - the next-gen Cyberslug

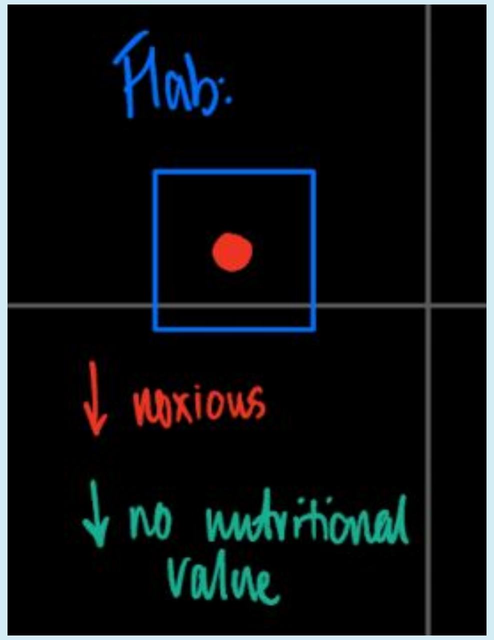
What does it do better than our previous model?

- Capable of associative learning;
  - Instead of eating according to a probability, Gary will optimize his own diet
- Advanced Sensory System:
  - Gary can differentiate his prey according to his own internal satisfaction and satiation levels
  - Gary can identify different prey in a simulated environment according to their unique odor
  - Gary becomes desensitized to the reward spike offered by drugs - he also is capable of resensitization
  - Gary goes through withdrawal and feels pain, which affects his decision-making

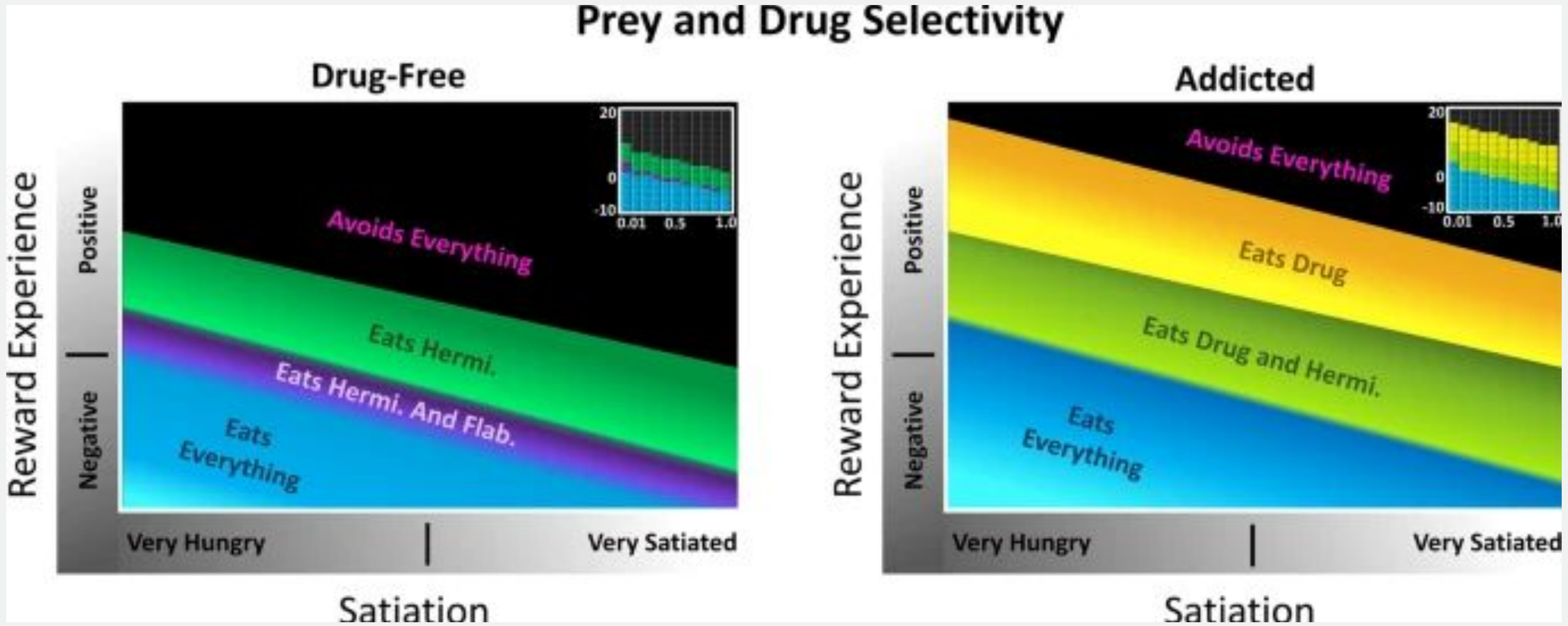


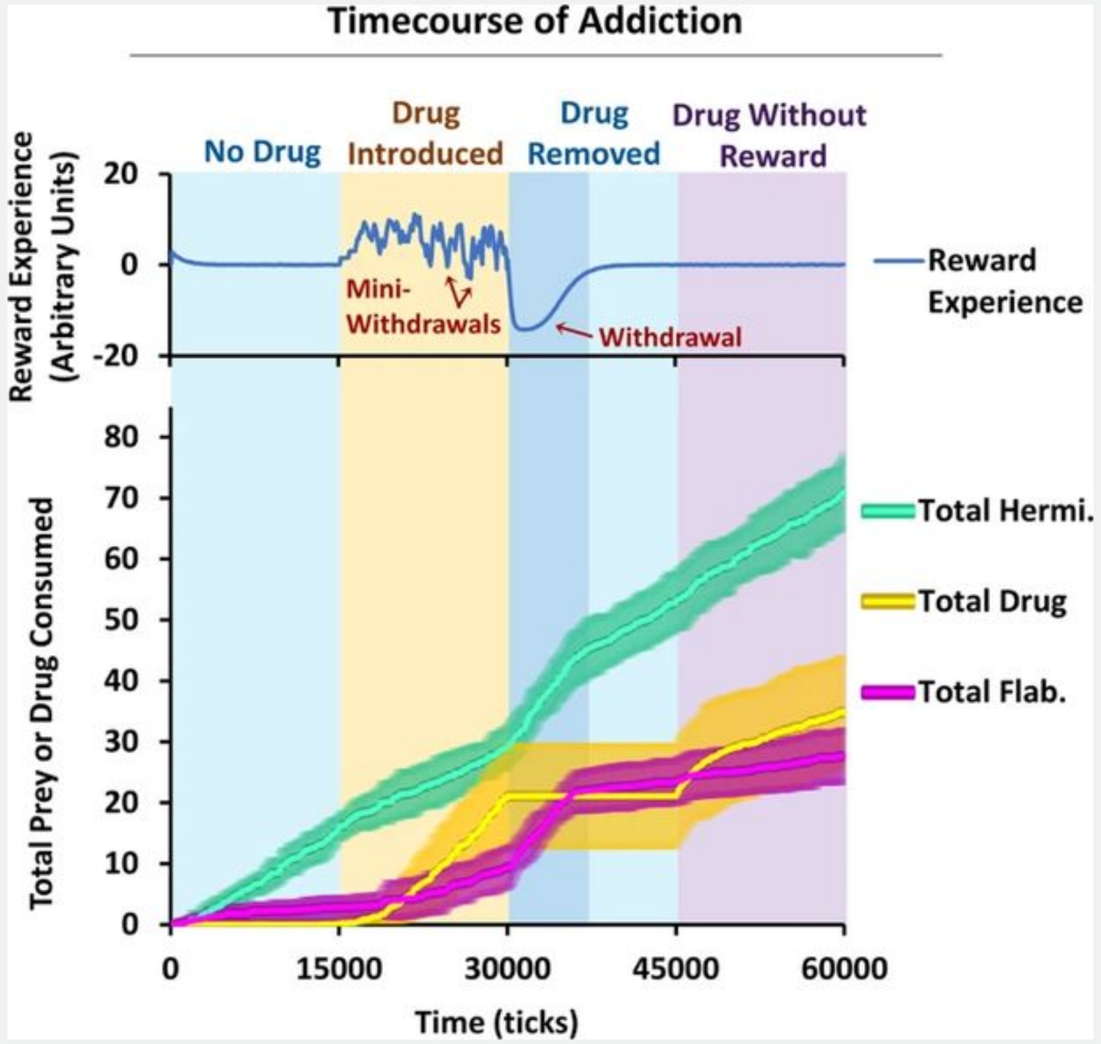






Conclusions from ASIMOV





What are the dangers of modeling this way?

- The over “mathematicilization” of behaviors - we reduce habits to probabilities and force logic where it may not belong
- Disregards neurochemical processes that fuel behavior
- Disregards social interactions that change behavior
- Disregards the individual and their cognitive processes entirely - what about patient autonomy and free will? What about the threats of paternalism?
- Disregards the opportunity for an addict to go into complete remission
    - Disregards the clinical perspectives and limitations involved in recovery
- Takes time and computational resources to calculate and is sensitive to changes to the initial conditions

More Rigorous Motivation for the Model of Addiction:

From Adi Jaffe's, PhD, *The Addiction Myth*, there are four main perspectives in treating addiction. We can model after each of this perspectives, which include:

The disease & epidemiological perspective:

How can diseases be spread? How can addiction be learned? How does it spread across members in a family?

The moralistic, value-based perspective:

Is it a moral failure to be an addict? What does it mean to be disciplined? Is addiction a lack of discipline?

The psychological & cognition perspective:

What role does trauma and environment play in developing harmful behaviors, like addiction?

The social perspective:

How does the community enable this behavior? How does it prevent it?

Other Important Limitations to Consider

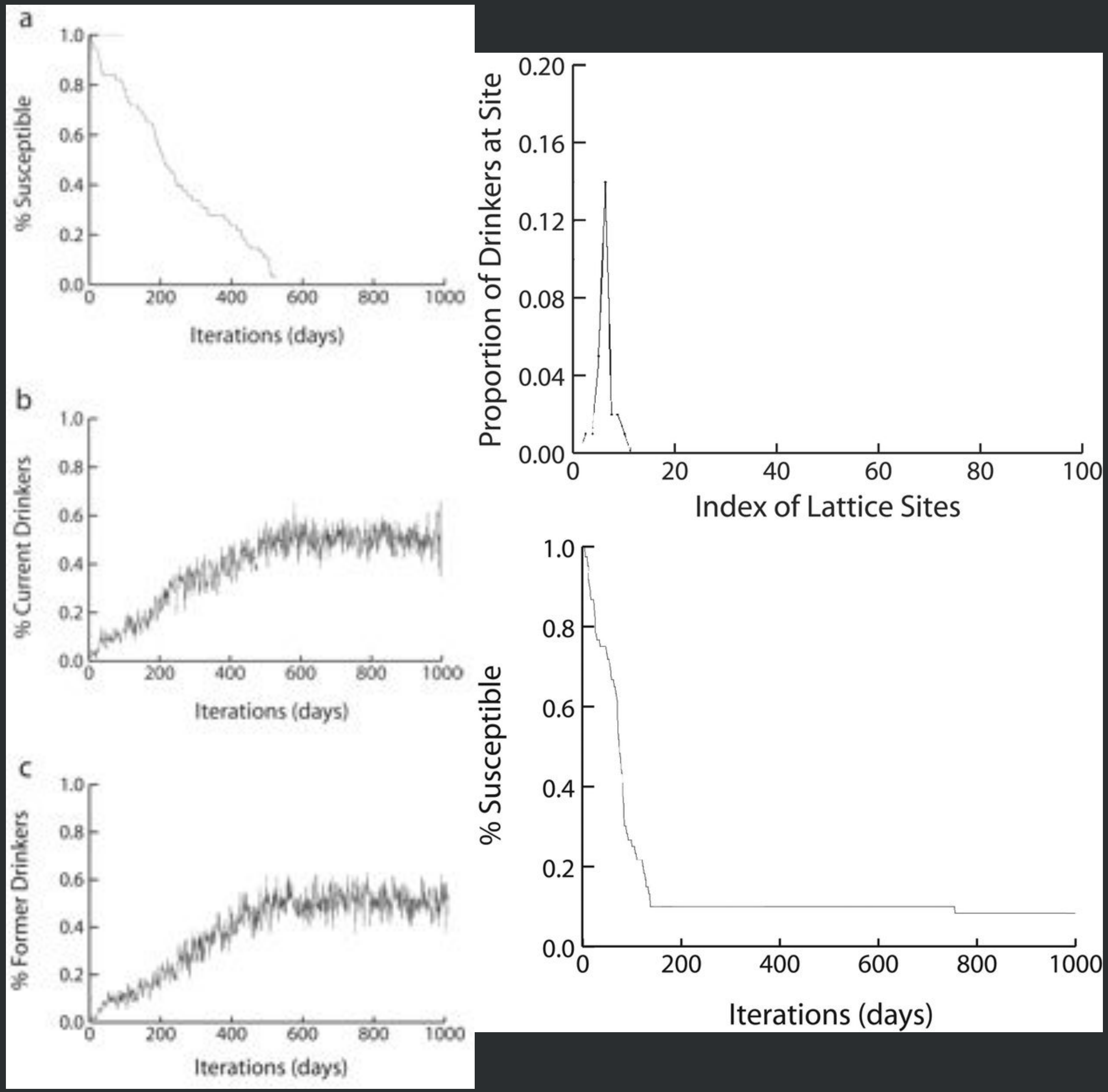
- Natural curiosity and novelty-seeking behavior
- Limited processing power & resources
- What about the clinicians who are involved in the treatment of the patient? How do we model the informed consent process?
- What about how the legislation treats patients? How is their journey reflected in these models?
- What about socioeconomic status? What about qualitative features and their influence in various social interactions? What about family history?
- What about the identity of the individual and the function of their use?

Advanced Agent-Based Modeling

- Essentially a simulation of a lower-fidelity reality:
  - Subtypes of agents are like different archetypes of people
  - The environment is entirely in our control
- Governed by preset rules:
  - Controls interactions in terms of the individual
  - We can introduce risk factors and measure their effects
- Can be as complex or as simple as desired:
  - Allows flexibility in terms of scaling the model (ie. how many agents and the environment size)
- Can be composed of multiple different learning algorithms:
  - Allows for more complex, individual agents
  - Allows for more emotional capacity; fear, anger, irrationality, etc.

Agent-Based Models in Action

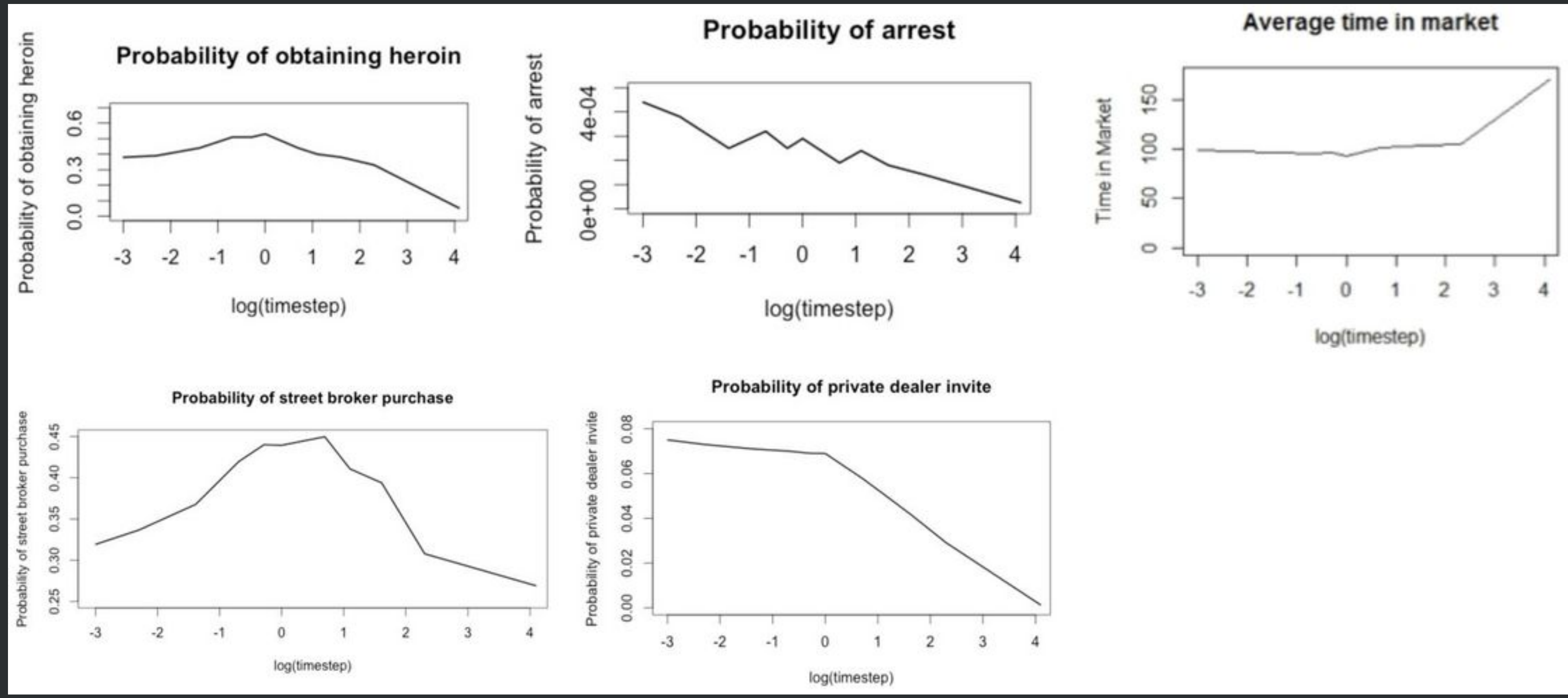
Effect of introducing bars on the population of drinkers:



Simulating visits and bed occupancy in a hospital:

Number of Doctor Visits	Actual	Model	Days in Hospital	Actual	Model
Mean	3.33	3.67	Mean	6.95	7.35
Std Dev	6.39	5.97	Std Dev	11.81	8.37
Median	2	2	Median	3	4
Max	58	71	Max	94	63
T-Stat	1.23		T-Stat	0.87	
P-Value	0.327		P-Value	0.327	

Simulated heroin addict activity:



The Dangers of Modeling and "Overmathematicalization"

- Reduces individuality; no one is born the same, yet we must assume so
- Relies on pure logic; there is currently little room for emotion or doubt
- What about understanding the underlying reason
- What about the researcher's and developer's biases? How does that shape the model?
- What if the math is wrong? What if a solution isn't optimal in theory, but effective in practice? And vice versa?
- What about those that fall into the margins of the statistics? Can we design a treatment plan that provide equitable, accessible, and fair care to all? How is that different in theory and practice?
- How is the use of modeling susceptible to perpetuating negative consequences?

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