Definition 0.1. Models: abstractions/approximations to reality/ absolute truth/ system/ phenomenon

Examples of Models:

- model airplane $\rightarrow$ airplane
- street map $\rightarrow$ city streets
- wind tunnel $\rightarrow$ airflow

"All models are wrong (not reality) but some are useful." -George Box.
Useful in the sense of providing predictions (what happened in a certain situation) and explanations (what makes the world tick?)
Data via simulation and data via direct measurement validate each other.
Why not just go with data via direct measurements? There is more control with simulations rather than in reality.

Definition 0.2. Validation: comparison of the measured data to the prediction; if they are "close", then the model is real; if not, we can rebuild the model, iterate and go closer.

Model: "Early to bed early to rise makes a man healthy, wealthy and wise.'"
Let's take this aphorism and see if it's a valid model.

$$\begin{bmatrix} \text{healthy} \\ \text{wealthy} \\ \text{wise} \end{bmatrix} = f(\text{bedtime, waketime})$$

The LHS is the output while the RHS is the inputs.
This model is "imprecise;" we need numbers and numerical measurements.

Let's take our parameters and outputs to see if there is a way to acquire numerical measurements.

- bedtime: average of 24 hr time
- wake time: average of 24 hr time
- health: longetivity
- wealth: net worth
- wisdom

Mathematical Model (MM) $\in$ Models

- MMs have numeric inputs and outputs
- MMs are related by an equal sign

Famous Examples:

$$\underbrace{F}_{\text{output}} = \underbrace{ma}_{\text{2 inputs}} = f(m, a)$$

$$E = mc^2 = f(m, c)$$

Let $y = t(z_1, z_2, \ldots, z_t)$ where y is output/ response/ outcome/ endpoint/ dependent variable, $(z_1, z_2, \ldots, z_t)$ is "true" causal input information and t is "true" relationship between the causal inputs and the output.

An example of this relationship is with credit worthiness where $y \in \{\text{creditworthy, uncreditworthy}\}$ or $y = \{0, 1\}$ with y being our output space.

True Causal Inputs:

- z_1: has enough money at the time the loan is due $\in \{0, 1\}$
- z_2: unforeseen emergency $\in \{0, 1\}$
- z_3: criminal intent

Bigger Problem: $\{z_1, z_2, z_3\}$ are unobservable, not able to be measured, un-accessable, etc
Smaller Problem: don't know t