

Models, Idealizations, and Abstraction

Tools for Good Thinking

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Intro to Logic

What is a Model? Understanding Simplified Representations

- A **model** is a simplified version of something complex that helps us understand, predict, or explain how things work.
- Models intentionally leave out certain details to focus on what matters most for a specific purpose.
- We use models every day without realizing it—from toy cars to mental pictures of how our friends might react to news.
- The key insight is that all models are "wrong" in some way because they're simpler than reality, but many are still incredibly useful.

Remember

A model's value comes not from being perfect, but from being useful for its intended purpose.

Why We Need Models: Making Complex Things Understandable

- The real world contains far too much information for our brains to process all at once.
- Models act as **cognitive tools** that reduce this overwhelming complexity to manageable chunks we can work with.
- Without models, we couldn't make predictions, plan for the future, or communicate complex ideas to others.
- Scientists, engineers, teachers, and even artists all rely on models to do their work effectively.

Example

When giving directions to your house, you don't describe every tree and crack in the sidewalk—you create a simple model using major landmarks and street names.

Abstraction: The Art of Leaving Things Out

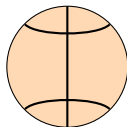
- **Abstraction** is the process of removing specific details to reveal general patterns or essential features.
- When we abstract, we deliberately ignore certain aspects of reality to highlight others that matter more for our purposes.
- Good abstraction requires judgment about what to keep and what to discard—this is a skill that improves with practice.
- The same real-world situation can be abstracted in different ways depending on what we're trying to understand or accomplish.

Warning

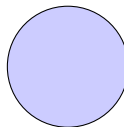
Too much abstraction makes a model useless; too little makes it too complicated to work with.

Idealization: When Perfect Spheres Don't Exist

- **Idealization** is a special type of abstraction where we imagine perfect or extreme versions of things that don't exist in reality.
- Physics teachers talk about "frictionless surfaces" and "perfect vacuums"—these idealizations help us understand fundamental principles.
- In everyday life, we idealize when we think about "the perfect friend" or "an absolutely fair game."
- Idealizations are powerful because they show us limiting cases and help us understand what happens when certain factors are pushed to extremes.



Real Basketball



Idealized Sphere

Maps as Models: Why Your GPS Doesn't Show Every Blade of Grass

- Maps are perfect examples of models because they represent three-dimensional space on a two-dimensional surface.
- Every map involves **selective representation**—showing roads but not individual houses, or showing countries but not cities.
- The level of detail in a map depends on its purpose: a hiking map shows elevation changes, while a subway map ignores them completely.
- Your GPS map updates in real-time but still leaves out countless details like the color of buildings or the number of windows.

Map Type	Shows	Ignores
Road Map	Streets, highways	Building heights
Topographic	Elevation, terrain	Traffic patterns
Political	Borders, capitals	Physical features
Weather	Temperature, precipitation	Street names

The Subway Map Example: When Distortion Helps

- The famous London Underground map **deliberately distorts** geographic reality to make the system easier to navigate.
- Stations are evenly spaced on the map even though they're not in real life, and the Thames River is simplified to a few straight lines.
- This "wrong" map is more useful than a geographically accurate one because it optimizes for its purpose: helping people navigate between stations.
- The map's designer, Harry Beck, realized that subway riders care about connections and sequence, not precise distances or directions.

Design Principle

The best model isn't the most accurate one—it's the one that best serves its intended users and purpose.

London Underground Map

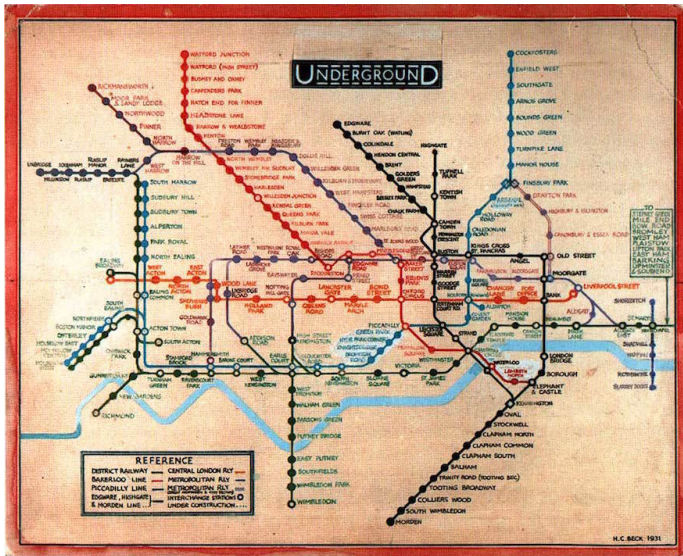


Figure: The 1931 map that changed the way subway maps were drawn.

Scale Models: From Toy Planes to Architectural Blueprints

- **Scale models** maintain proportional relationships while changing size, allowing us to work with things too large or small to handle directly.
- Architects build small models of buildings to test designs, while engineers use scaled-up models of tiny components to understand how they work.
- The key to scale models is maintaining **relevant proportions**—a 1:100 model means every dimension is exactly 100 times smaller.
- Some properties scale perfectly (like shape), while others don't (like material strength), which is why we must be careful when interpreting scale models.

Example

- Model airplane: Tests aerodynamics at 1:50 scale
- Architectural model: Shows building appearance at 1:200 scale
- Molecular model: Enlarges atoms billions of times for visibility
- Solar system model: Shrinks vast distances to fit in a classroom

Mental Models: How We Think About Everyday Life

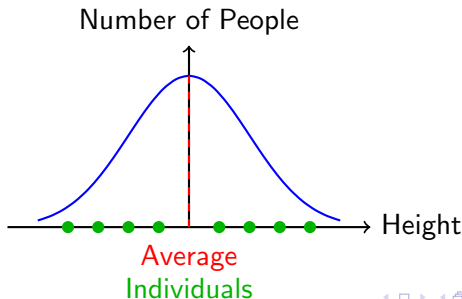
- **Mental models** are the internal representations we use to understand how things work and predict what will happen.
- You have mental models for everything from how your friends will react to jokes to how long your homework will take.
- These models are built from experience and constantly updated—when surprised, we revise our mental models to be more accurate.
- We often don't realize we're using mental models until they fail us and we have to consciously think about why our expectations were wrong.

Common Mental Model Errors

- Assuming everyone thinks like you do
- Oversimplifying complex situations
- Not updating models when given new information
- Applying models outside their useful range

The "Average Person" Model: Statistics and Simplification

- The **statistical average** is a model that represents an entire group with a single number or set of characteristics.
- When we say "the average teenager needs 9 hours of sleep," we're creating a simplified model that ignores individual variation.
- This model is useful for making general predictions and policies, but it can be misleading if we forget that no real person is perfectly average.
- Statistical models help us see patterns in large groups that would be invisible if we tried to track every individual separately.



Weather Models: Predicting the Unpredictable

- Weather models use **mathematical equations** to simulate how air pressure, temperature, and moisture interact in the atmosphere.
- These models divide the atmosphere into millions of 3D boxes and calculate how conditions in each box change over time.
- Even the best weather models lose accuracy after about 10 days because tiny measurement errors grow exponentially—this is called **chaos theory**.
- Meteorologists run multiple models with slightly different starting conditions to estimate the uncertainty in their predictions.

Model Limitations

Weather models can predict general patterns (like storm systems) better than specific details (like exactly where rain will fall in your neighborhood).

Economic Models: Supply, Demand, and Reality

- Economic models like **supply and demand curves** simplify the incredibly complex world of human buying and selling behavior.
- These models assume people are "rational actors" who always try to maximize their benefit, though real people often act emotionally or irrationally.
- The basic model ignores factors like advertising, social pressure, and habit, but it still helps predict how prices change when supply or demand shifts.
- Economists build more complex models by adding factors back in, but even these can't capture all the messiness of real human behavior.

Example

Simple Supply and Demand Model Assumptions:

- Perfect information (everyone knows all prices)
- No transaction costs (buying is free and instant)
- Identical products (all apples are the same)
- Many buyers and sellers (no monopolies)

The Atom Model: From Plum Pudding to Electron Clouds

- Scientific models evolve as we gather new evidence—the model of the atom has changed dramatically over the past 200 years.
- Thomson's "plum pudding" model imagined electrons embedded in positive charge like raisins in pudding, but experiments proved this wrong.
- Bohr's model showed electrons in fixed orbits like planets, which explained some observations but failed to explain others.
- Today's **quantum mechanical model** describes electrons as probability clouds, which is harder to visualize but matches experimental results better.

Model	Year	Key Feature
Dalton	1803	Solid spheres
Thomson	1897	Plum pudding
Rutherford	1911	Nucleus + empty space
Bohr	1913	Fixed electron orbits
Quantum	1926	Probability clouds

Sports Statistics: Modeling Athletic Performance

- Sports use **statistical models** to reduce complex athletic performances to numbers that can be compared and analyzed.
- A basketball player's "shooting percentage" models their scoring ability with a single number, ignoring factors like defense pressure or game importance.
- Advanced models like "player efficiency rating" try to capture more aspects of performance, but they still can't measure intangibles like leadership or clutch performance.
- These models help coaches make decisions and fans understand the game, but overreliance on statistics can miss crucial human elements.

The Moneyball Revolution

Baseball's Oakland Athletics used statistical models to find undervalued players, proving that better models can provide competitive advantages even with limited resources.

Social Media Algorithms: Models of Human Behavior

- Social media platforms use **algorithmic models** to predict what content you'll find engaging based on your past behavior.
- These models track metrics like clicks, likes, viewing time, and shares to build a profile of your interests and preferences.
- The algorithm's model of you is constantly updating—every interaction teaches it more about what keeps you scrolling.
- These models are powerful but can create "filter bubbles" where you only see content that matches the algorithm's model of your interests.

How the Model Sees You

You = Past Clicks + Time Spent + Similar Users + Trending Topics

This simplified equation can predict your behavior surprisingly well, but it reduces your complex personality to data points.

Video Game Physics: When Close Enough is Good Enough

- Video games use **simplified physics models** that create believable movement without calculating every real-world force.
- Game physics often use "cheats" like invisible walls, magnetized ledges for climbing, and generous collision detection to make games fun rather than realistic.
- Racing games might model tire friction and aerodynamics, but ignore factors like tire temperature or microscopic road texture that would make the game too complex.
- The goal is creating an experience that "feels right" to players, not perfectly simulating reality—this is **selective realism**.

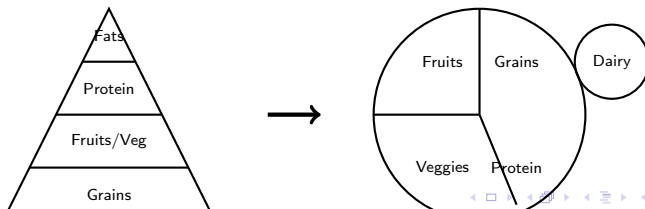
Example

Common Video Game Physics Simplifications:

- Gravity that only affects the player (not hair or clothing)
- "Coyote time"—letting players jump after leaving a platform
- Bullets that travel in straight lines (ignoring wind and gravity)
- Health that regenerates by waiting (not medical treatment)

The Food Pyramid: Modeling Nutrition Simply

- The food pyramid was a **visual model** designed to communicate complex nutritional science through a simple shape everyone could understand.
- This model grouped hundreds of different foods into just a few categories and used spatial size to represent recommended proportions.
- The pyramid model had flaws—it oversimplified nutrition and didn't account for food quality differences within categories (whole grains vs. white bread).
- It was replaced by MyPlate in 2011, showing how models must evolve when we realize their limitations or when our understanding improves.



Stereotypes as Flawed Models: The Danger of Over-Simplification

- **Stereotypes** are mental models that assume all members of a group share certain characteristics—they're the lazy person's abstraction.
- While our brains naturally categorize to handle information efficiently, stereotypes fail because they ignore individual differences and complexity.
- These flawed models can lead to discrimination, missed opportunities, and self-fulfilling prophecies when people are treated according to the stereotype.
- The key difference between useful models and harmful stereotypes is that good models update with new information, while stereotypes resist change.

Critical Thinking Check

When you catch yourself thinking "All X people are Y," you're using a stereotype model. Ask yourself: What evidence supports this? What examples contradict it? Am I missing important individual differences?

Scientific Models: From Hypothesis to Theory

- Scientific models begin as **hypotheses**—educated guesses about how something works based on initial observations.
- Scientists test these models through experiments, looking for evidence that supports or contradicts their predictions.
- Models that consistently match experimental results and make accurate predictions may become **theories**—our best current explanations.
- Even well-established theories remain models that could be replaced if new evidence shows they're incomplete or wrong.

The Scientific Model Cycle

Observation → Hypothesis → Prediction → Experiment →
Revision → Better Model → More Testing → Theory

This cycle never truly ends—even our best theories are still models subject to revision.

The Solar System Model: Textbooks vs. Reality

- Textbook diagrams show planets in neat circular orbits around the sun, all conveniently fitting on one page.
- These models grossly distort both **scale and distance**—if Earth were a pea, Jupiter would be 1000 feet away and the sun would be a beach ball.
- The orbits aren't circles but ellipses, planets don't orbit in the same plane, and the sun itself wobbles as planets pull on it.
- Despite these "lies," the simplified model successfully teaches the basic concept of planetary motion better than accurate scale would.

What Textbooks Show	Reality
Circular orbits	Elliptical orbits
Equal spacing	Vast empty distances
Same orbital plane	Tilted at various angles
Stationary sun	Sun orbits galactic center
Planets visible size	Planets are tiny dots

The Solar System: Scale Model

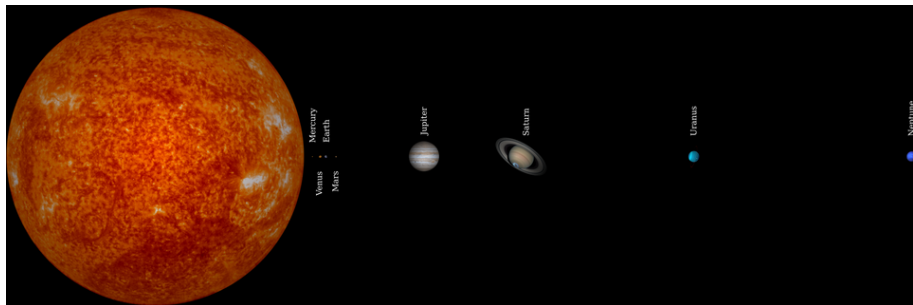


Figure: Earth is barely visible!.

Choosing the Right Level of Detail: The Goldilocks Problem

- Creating useful models requires finding the **Goldilocks zone**—not too simple, not too complex, but just right for the purpose.
- A model with too little detail fails to capture important behavior, while too much detail makes it unwieldy and hard to understand.
- The "right" level depends entirely on what you're trying to accomplish—a pilot needs a different weather model than someone planning a picnic.
- This judgment improves with experience as you learn which details matter for different purposes and which can safely be ignored.

Example

Modeling a School Day:

- Too simple: "I go to school" (misses all useful detail)
- Just right: Seven periods, lunch, passing time (captures structure)
- Too complex: Every conversation, step, and thought (overwhelming)
- Purpose matters: Add detail for scheduling, remove it for explaining to grandparents

When Models Break: Recognizing Limitations

- Every model has **boundary conditions**—situations where it stops working because assumptions no longer hold true.
- Newton's laws of motion work perfectly for everyday speeds but break down as objects approach the speed of light, requiring Einstein's relativity.
- Economic models failed to predict the 2008 financial crisis because they didn't account for widespread irrational behavior and systemic risks.
- Recognizing when you're pushing a model beyond its limits is a crucial skill that prevents dangerous overconfidence in predictions.

Warning Signs of Model Failure

- Predictions become wildly inaccurate
- Small changes cause huge differences in outcomes
- The model requires increasingly complex "fixes"
- Real-world behavior contradicts basic assumptions

Mathematical Models: Equations as Abstractions

- **Mathematical models** use equations to represent relationships between different quantities in the real world.
- The equation $d = rt$ (distance equals rate times time) models motion by ignoring everything except speed, time, and distance traveled.
- These models are powerful because math allows us to manipulate symbols instead of dealing with messy reality directly.
- Mathematical models can make precise predictions, but their accuracy depends entirely on whether the simplifying assumptions match the situation.

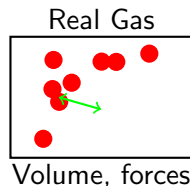
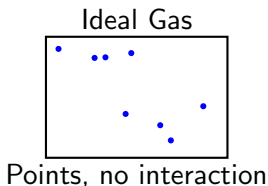
From Reality to Equation

Real situation \rightarrow Identify key variables \rightarrow
Assume relationships \rightarrow Write equation \rightarrow
Solve mathematically \rightarrow Interpret results

Each step involves choices about what to include and what to ignore.

The Ideal Gas Law: When Molecules Don't Interact

- The **ideal gas law** ($PV = nRT$) models gas behavior by assuming molecules are point particles that don't interact with each other.
- Real gas molecules have volume and attract or repel each other, but these complications often don't matter much at normal conditions.
- At high pressure or low temperature, real gases deviate significantly from the ideal model because molecules are squeezed together.
- Scientists created more complex models (like van der Waals equation) that add back some reality when the simple model isn't accurate enough.



Personality Models: Myers-Briggs and Beyond

- Personality models like **Myers-Briggs** try to categorize the infinite variety of human personalities into a manageable number of types.
- These models can provide useful vocabulary for discussing personality differences and help people understand their own tendencies.
- However, human personality is far more complex and fluid than any model suggests—people behave differently in different contexts.
- The danger comes when we treat these models as fixed truths rather than useful simplifications for specific purposes like team building.

Example

Popular Personality Models:

- Myers-Briggs: 16 types based on 4 dimensions
- Big Five: Rates 5 traits on continuous scales
- Enneagram: 9 interconnected personality types
- Each captures some truth but misses individual complexity

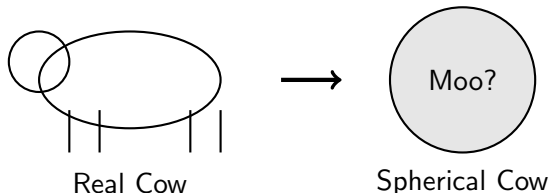
Computer Simulations: Digital Models of Reality

- **Computer simulations** are models that use computational power to track many interacting parts over time.
- Flight simulators model aircraft physics, weather, and pilot controls to train pilots without risk or expense of real flying.
- Climate models divide Earth into millions of grid cells and simulate decades of weather to predict long-term changes.
- These digital models can include more complexity than paper-and-pencil models, but they still require simplifying assumptions about what matters.

Simulation Type	Models	Ignores
Flight simulator	Aerodynamics, controls	Bird strikes, wear
Climate model	Ocean, atmosphere	Individual clouds
Traffic simulation	Driver behavior	Radio stations
Disease spread	Contact patterns	Individual immunity

The Spherical Cow: A Classic Physics Joke About Over-Idealization

- Physicists joke about modeling a cow as a **sphere** to illustrate how scientific models can become absurdly oversimplified.
- The joke originated from physics problems that begin "Assume a spherical cow in a vacuum..." to eliminate messy biological reality.
- While it sounds ridiculous, spherical cow models can actually work for some calculations, like estimating how much hay a herd needs.
- The joke reminds us to always ask whether our simplifications have gone too far for the problem we're trying to solve.



Models in Medicine: From Anatomy Diagrams to Disease Spread

- Medical models range from **anatomical diagrams** that show body structure to epidemiological models that predict disease spread.
- The classic heart diagram shows four chambers and major vessels but ignores the electrical system, individual variation, and surrounding tissues.
- Disease spread models like SIR (Susceptible-Infected-Recovered) help predict pandemic behavior but assume uniform mixing of populations.
- Medical professionals must constantly balance simplified teaching models with the complex reality of individual patient cases.

The SIR Model

Susceptible \rightarrow Infected \rightarrow Recovered

This simple flow model helped predict COVID-19 spread, despite ignoring factors like asymptomatic cases, varying immunity, and behavior changes.

Time Management Models: Calendars and Schedules

- **Calendars and schedules** are models that represent the continuous flow of time as discrete blocks we can manipulate and plan.
- These models assume tasks fit neatly into time slots, but reality includes interruptions, transitions, and tasks that expand or contract.
- Different calendar models work for different people—some need hourly detail while others work better with flexible daily goals.
- The most common failure is creating an "ideal day" model that ignores how much time real activities actually take.

Example

Time Model vs. Reality:

- Schedule says: Math homework 7:00-8:00 PM
- Reality includes: Finding materials (10 min), mental transition (5 min), checking phone (15 min), actual work (45 min), cleanup (5 min)
- Effective models build in buffer time for reality

Building Good Models: Key Questions to Ask

- Before creating any model, ask "**What is my purpose?**"—a model for understanding differs from one for prediction or communication.
- Identify the essential features by asking "**What must I include?**"—these are the elements without which the model fails completely.
- Consider your audience with "**Who will use this model?**"—experts can handle more complexity than beginners.
- Finally, ask "**How will I know if it works?**"—good models have clear criteria for success or failure.

The Model Builder's Checklist

- 1 Define clear purpose and scope
- 2 List assumptions explicitly
- 3 Identify key variables and relationships
- 4 Choose appropriate level of detail
- 5 Plan how to test the model
- 6 Consider when the model might fail

Testing Models: Prediction vs. Reality

- The ultimate test of any model is whether its **predictions match reality** within acceptable error bounds.
- Good models make specific, testable predictions—vague models that can explain anything actually explain nothing.
- When predictions fail, it reveals either wrong assumptions, missing variables, or situations beyond the model's scope.
- Testing should include both typical cases where the model should work and edge cases where it might break down.

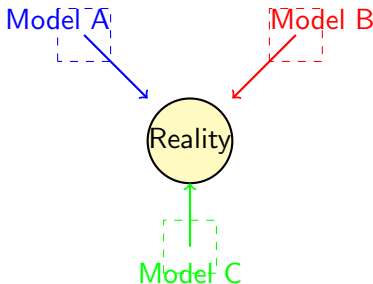
Example

Testing a Study Time Model:

- Model predicts: 2 hours study = B grade, 3 hours = A grade
- Test with real data: Track actual study time and grades
- Discover complications: Subject difficulty matters, quality beats quantity, some students need more time
- Refine model: Add subject difficulty multiplier and efficiency factors

Multiple Models: Why Different Views Matter

- Complex phenomena often require **multiple models** that each capture different aspects of reality.
- Light behaves as both a wave and a particle—physicists use whichever model works better for each situation.
- In business, financial models show profitability while organizational models show human relationships—both are needed for success.
- Using multiple models helps avoid the tunnel vision that comes from relying on a single perspective.



The Map-Territory Relationship: Models Are Not Reality

- Philosopher Alfred Korzybski famously said "**The map is not the territory**"—models represent reality but are not reality itself.
- It's easy to forget this distinction and start believing our models are more real than the messy world they represent.
- This confusion leads to problems like treating IQ scores as complete measures of intelligence or GDP as the sole measure of national success.
- Always remember that models are tools for thinking about reality, not substitutes for experiencing and observing the real world.

The Fundamental Warning

No matter how detailed, accurate, or useful a model becomes, it remains a simplified representation. The moment you forget this and mistake the model for reality itself, you've fallen into one of thinking's most dangerous traps.

Models in Decision Making: Pros and Cons Lists

- The humble **pros and cons list** is actually a decision-making model that simplifies complex choices into positive and negative factors.
- This model assumes all factors can be clearly categorized and that more items on one side means that choice is better.
- Advanced versions assign weights to different factors, recognizing that not all pros and cons matter equally.
- The model's simplicity is both its strength (easy to use) and weakness (ignores factor interactions and emotional elements).

Simple Model		Weighted Model	
Pros	Cons	Pros (Weight)	Cons (Weight)
Closer	Expensive	Closer (3)	Expensive (5)
Better teachers	Less diverse	Better teachers (4)	Less diverse (2)
Nice campus	Far from home	Nice campus (1)	Far from home (3)
Count: 3	Count: 3	Score: 8	Score: 10

Evolution of Models: How Our Understanding Improves

- Models evolve through a process of **iterative refinement**—each version builds on lessons learned from previous failures.
- Early models tend to be simple and capture only the most obvious features, like ancient astronomers tracking basic star movements.
- As we gather more data and identify model failures, we add complexity where needed while trying to maintain usability.
- Sometimes incremental improvements aren't enough, and we need **paradigm shifts**—completely new models that approach problems differently.

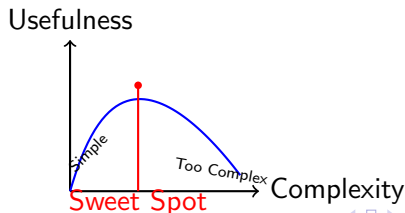
Model Evolution Pattern

Simple observation → Basic model → Find exceptions →
Add complexity → Test again → Reach limits →
Revolutionary new approach → Repeat cycle

This pattern appears across all fields from physics to psychology.

The Cost of Complexity: When Simple Models Work Better

- Adding detail to models has **diminishing returns**—each new factor makes the model harder to use while providing less additional accuracy.
- Complex models require more data, more computation, and more expertise to use effectively than simple ones.
- In many situations, a simple model that's "good enough" beats a complex model that's theoretically better but practically unwieldy.
- The art lies in finding the sweet spot where additional complexity stops adding value for your specific purpose.



Thinking Like a Modeler: Applying These Tools to Your Life

- Recognizing models everywhere helps you think more clearly about **what assumptions you're making** in daily life.
- When facing problems, ask "What would a useful model of this situation include?" to identify key factors and relationships.
- Practice building multiple models of the same situation to avoid getting locked into one perspective or solution.
- Most importantly, stay humble about your models—be ready to revise or abandon them when reality proves them inadequate.

Example

Modeling Your Day Tomorrow:

- Energy model: When will I have high/low energy for different tasks?
- Time model: How long will activities actually take (with buffers)?
- Social model: Who will I interact with and how will that affect plans?
- Combine insights from all three for a realistic, flexible plan