

# Analological Reasoning

## How Humans Make Sense of the World

Brendan Shea, PhD

Introduction to Logic

# Lesson Overview: From Pattern Recognition to AI

- This lesson explores how humans use **analogical reasoning** - the process of understanding new situations by comparing them to familiar ones.
- We will examine why the human mind naturally thinks in analogies and how this shapes our understanding across different domains.
- You will learn to evaluate what makes analogies effective or misleading in science, ethics, and law.
- We conclude by comparing human analogical thinking with AI pattern recognition systems.

## Core Question

What makes some analogies powerful tools for understanding while others lead us astray?

# The Cognitive Architecture of Analogy-Making

- The human brain contains specialized regions that automatically search for **structural similarities** between different situations.
- **Working memory** allows us to hold multiple concepts simultaneously and map relationships between them.
- Our cognitive system prioritizes **relational matches** over surface features when making analogies.
- This architecture evolved because recognizing patterns across contexts provides survival advantages.

## Key Components

- 1 Pattern detection systems
- 2 Relational mapping processes
- 3 Similarity evaluation mechanisms

# Why Our Brains Default to Analogical Thinking

- Analogical thinking allows us to apply **previous knowledge** to novel situations without starting from scratch.
- It serves as a **cognitive shortcut** that saves mental energy and processing time.
- This default mode helps us navigate uncertainty by finding familiar patterns in unfamiliar contexts.
- **Evolutionary pressure** favored minds that could quickly recognize "this is like that" for rapid decision-making.

## Example

When early humans encountered a new predator, recognizing it as "like a lion" triggered appropriate defensive responses without direct experience.

# Everyday Examples of Analogical Reasoning

- **Learning:** "Multiplication is just repeated addition" helps students understand a new operation through a familiar one.
- **Communication:** "The internet is like a highway" explains data flow using traffic and routes.
- **Problem-solving:** "This math problem is like the one we did yesterday" recognizes similar structure despite different numbers.
- **Social understanding:** "She's going through what I went through last year" applies personal experience to understand others.

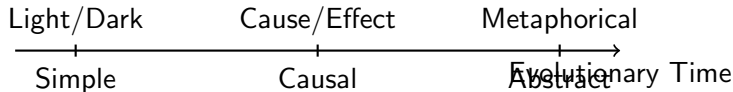
## Example

When teaching fractions, we say "cutting a pizza into slices" because:

- Source: Pizza (familiar, concrete)
- Target: Fractions (abstract, new)
- Mapping: Whole pizza = 1, slices = parts, sharing = division

# Pattern Recognition and the Evolution of Reasoning

- **Pattern recognition** emerged as a fundamental survival skill in early organisms detecting regularities in their environment.
- Human reasoning evolved from simple stimulus-response patterns to complex **abstract pattern matching**.
- Our ancestors who could recognize that "dark clouds mean rain" gained advantages in planning and resource management.
- This capacity expanded from physical patterns to social, causal, and conceptual patterns over evolutionary time.



# From Metaphor to Model: The Spectrum of Analogical Thought

- Analogical thinking exists on a spectrum from loose **metaphors** to precise **scientific models**.
- **Metaphors** highlight selected similarities while ignoring differences (e.g., "time is money").
- **Analogies** make explicit comparisons between domains to explain or argue (e.g., "the heart is like a pump").
- **Models** systematically map multiple relationships from one domain to another (e.g., the planetary model of the atom).

## Increasing Precision

Type	Purpose	Rigor
Metaphor	Illuminate	Low
Analogy	Explain/Argue	Medium
Model	Predict/Test	High

# Anatomy of an Analogy: Source, Target, and Mapping

- Every analogy contains a **source domain** (the familiar concept) and a **target domain** (the unfamiliar concept being explained).
- The **mapping** identifies which elements in the source correspond to elements in the target.
- Strong analogies preserve **structural relationships** between elements, not just surface features.
- The process involves selecting relevant features while ignoring irrelevant differences between domains.

## Example

**Analogy:** "The atom is like a solar system"

- Source: Solar system (familiar)
- Target: Atom (unfamiliar)
- Mapping: Sun → nucleus, planets → electrons, orbits → electron paths



# Structural Alignment: When Relationships Matter More Than Objects

- **Structural alignment** means matching the relationships between elements rather than the elements themselves.
- Good analogies preserve **higher-order relations** - relationships between relationships.
- Surface similarities (color, size, shape) are less important than **relational structure** (causation, proportion, function).
- This principle explains why "the mind is a computer" works better than "the mind is a filing cabinet."

## Key Insight

The power of an analogy lies not in how similar things look, but in how similarly they behave or relate to other elements in their respective systems.

# Surface vs. Deep Features in Analogical Reasoning

- **Surface features** are immediately observable characteristics like appearance, color, or size.
- **Deep features** involve underlying relationships, functions, or causal structures.
- Novices tend to focus on surface similarities, while experts recognize deep structural patterns.
- Effective analogical reasoning requires looking past superficial resemblance to find meaningful connections.

## Common Mistake

Students often group physics problems by surface features (inclined planes, pulleys) rather than deep principles (conservation of energy, Newton's laws).

# The Role of Context in Analogical Transfer

- **Context** determines which features of an analogy are relevant and which should be ignored.
- The same source can map to different targets depending on the **purpose** of the comparison.
- **Pragmatic constraints** shape how we interpret and apply analogies in real situations.
- Cultural background influences which analogies feel natural or forced to different audiences.

## Example

"Life is a journey" emphasizes different aspects in different contexts:

- Career counseling: progression, milestones, destinations
- Grief counseling: rough roads, companions, continuing forward
- Education: exploration, discovery, growth

# Criteria for Evaluating Analogical Arguments

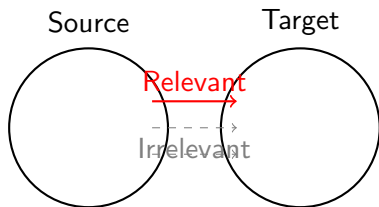
- **Relevance:** The shared properties must be relevant to the conclusion being drawn.
- **Quantity:** More similarities generally strengthen an analogy, but quality matters more than quantity.
- **Diversity:** Similarities across different types of features provide stronger support.
- **Disanalogy:** Important differences between source and target can weaken or defeat the argument.

## Evaluation Checklist

- 1 Are the similarities relevant to the conclusion?
- 2 Do the differences matter for this purpose?
- 3 Is the source well-understood?
- 4 Are there alternative analogies to consider?

# Relevant Similarities and the Problem of Selection

- Any two things share infinite similarities and differences, creating a **selection problem**.
- **Relevance** depends on the specific claim or conclusion the analogy supports.
- We must identify which shared features actually matter for the **inferential goal**.
- Background knowledge and theory guide us in selecting appropriate features to compare.



# When Dissimilarities Matter: Negative Analogy

- **Negative analogy** refers to the ways in which the source and target differ.
- Some differences are harmless to the analogy, while others are **defeaters** that undermine the comparison.
- A difference becomes critical when it affects the specific relationship or property being transferred.
- Recognizing relevant dissimilarities helps us avoid overextending analogies beyond their useful scope.

## Critical Question

Does this difference break the relationship I'm trying to map from source to target?

# The Danger of Superficial Resemblance

- **Superficial resemblance** occurs when things look similar but lack deep structural correspondence.
- This mistake often leads to false predictions and poor decision-making.
- Marketing and propaganda frequently exploit surface similarities to create misleading associations.
- Training in analogical reasoning helps us resist being fooled by mere appearance.

## Example

**Misleading Analogy:** "This alternative medicine works like traditional medicine"

- Surface similarity: Both come in pill form
- Missing deep structure: No tested biological mechanism
- Result: False confidence in effectiveness

# Historical Examples: From Plato's Cave to Darwin's Tree

- **Plato's Cave:** Reality is to shadows as true knowledge is to sensory experience.
- **Newton's Clockwork Universe:** The cosmos operates like a precise mechanical clock.
- **Darwin's Tree of Life:** Species relationships branch like a growing tree.
- **Freud's Iceberg:** Conscious thought is the tip; the unconscious lies beneath.

## Why These Analogies Endured

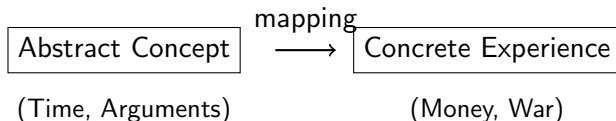
These analogies succeeded because they:

- Mapped complex abstract ideas to concrete images
- Preserved crucial relationships
- Generated testable predictions



# Everyday Analogies We Live By

- **Time is money:** We "spend," "save," "waste," and "invest" time.
- **Arguments are war:** We "defend" positions, "attack" weak points, and "win" debates.
- **Ideas are food:** We "digest" information, "chew on" problems, and find some ideas "hard to swallow."
- **Organizations are organisms:** Companies "grow," have "healthy" cultures, and can "die."



# Models as Extended Analogies in Scientific Discovery

- Scientific **models** are systematic analogies that map multiple relationships from familiar to unfamiliar domains.
- Unlike simple analogies, models generate **quantitative predictions** that can be tested experimentally.
- Scientists use models as **thinking tools** to explore implications and design new experiments.
- The best models reveal unexpected connections and suggest new research directions.

## From Analogy to Model

Simple Analogy	Scientific Model
"Heart is like a pump"	Cardiac pressure equations
"Brain is like a computer"	Neural network algorithms
"DNA is like a code"	Base-pair transcription rules

# Case Study: The Wave-Particle Duality of Light

- Scientists initially debated whether light was analogous to **water waves** or **flying particles**.
- Wave analogy explained: interference patterns, diffraction, and refraction phenomena.
- Particle analogy explained: photoelectric effect and discrete energy packets.
- The resolution required accepting that light doesn't perfectly match either familiar analogy.

## Example

The double-slit experiment revealed the limitation of classical analogies:

- Individual photons (particle-like) create interference patterns (wave-like)
- Neither waves nor particles from everyday experience behave this way
- New quantum framework transcended both analogies

# When Scientific Analogies Mislead: The Ether Hypothesis

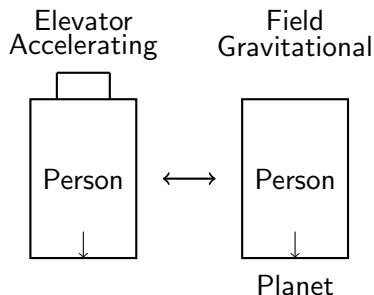
- 19th-century physicists assumed light waves needed a **medium** like sound waves need air.
- They invented "luminiferous ether" by analogy to other wave phenomena.
- This analogy led to decades of failed experiments searching for ether's properties.
- The Michelson-Morley experiment finally showed the analogy was fundamentally flawed.

## Lesson Learned

Even productive analogies have limits - scientific progress often requires abandoning familiar comparisons for genuinely new concepts.

# Thought Experiments as Analogical Tools

- **Thought experiments** use imaginative analogies to explore logical consequences of theories.
- They allow scientists to test ideas when real experiments are impossible or impractical.
- Famous examples include Einstein's elevator, Schrödinger's cat, and Maxwell's demon.
- These analogical scenarios reveal hidden assumptions and paradoxes in our theories.



# The Computer Model of Mind: Strengths and Limitations

- The **computational theory of mind** treats mental processes as information processing operations.
- Strengths: Explains memory storage, logical reasoning, and step-by-step problem solving.
- Limitations: Struggles with consciousness, emotions, and contextual understanding.
- This analogy revolutionized cognitive science but may constrain how we think about minds.

## Mapping the Analogy

- Hardware → Brain structure
- Software → Mental processes
- Input/Output → Perception/Action
- Bugs → Mental disorders (problematic?)

# DNA as Code: A Productive Metaphor

- The **genetic code** analogy helped scientists understand how DNA stores and transmits information.
- *DNA is like an instruction book (or computer program) for building proteins. Genes are like chapters.*
- This framing led to breakthroughs in sequencing, gene editing, and synthetic biology.
- The analogy suggests we can "debug" genetic diseases and "reprogram" organisms.
- However, biological systems are messier than computer code, with complex feedback loops.

## Example

Successful predictions from the code analogy:

- Four-letter alphabet (A, T, G, C) → words (codons) → sentences (genes)
- Copy errors → mutations
- Reading frames → translation mechanisms

# Moral Reasoning Through Analogical Cases

- Ethical reasoning often proceeds by finding **analogous cases** where our intuitions are clearer.
- We test moral principles by applying them to similar situations and checking for consistency.
- **Case-based reasoning** helps us navigate novel ethical dilemmas using established precedents.
- The challenge lies in determining which features are morally relevant for comparison.

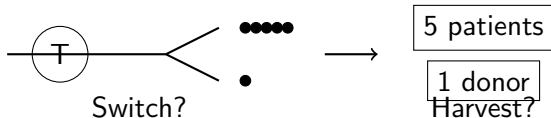
## Key Ethical Question

If we accept X in situation A, must we also accept Y in analogous situation B?



# The Trolley Problem and Its Analogical Extensions

- The **trolley problem** uses a concrete scenario to explore abstract principles about harm and intention.
- *Suppose a runaway trolley is headed toward five workers—it will kill them if not stopped. You are standing near a switch that will redirect this trolley so it kills one worker on a different track instead.*
- Variations test our intuitions: switching tracks vs. pushing someone, acting vs. allowing harm.
- These thought experiments reveal tensions between **utilitarian** and **deontological** ethics.
- Real-world applications include medical triage, autonomous vehicles, and military decisions.



# Using Analogies to Expand Our Moral Circle

- **Moral progress** often occurs when we recognize analogies between accepted and contested cases.
- Historical example: Arguments against slavery drew analogies to accepted rights of free persons.
- Contemporary debates use analogical extension: animal rights, AI rights, environmental protection.
- The **expanding circle** of moral concern relies on seeing similarities across boundaries.

## Pattern of Moral Expansion

- 1 Establish principle for core case (humans deserve respect)
- 2 Identify relevant similarity (capacity to suffer)
- 3 Extend principle to analogous beings (animals can suffer too)
- 4 Overcome resistance from surface differences

# When Ethical Analogies Break Down

- Ethical analogies fail when **morally relevant differences** are overlooked or minimized.
- False analogies can justify harmful actions by focusing on superficial similarities.
- Context and relationships matter: what works in one domain may not transfer to another.
- We must carefully examine whether the features that ground moral status are truly shared.

## Warning Signs

An ethical analogy may be flawed when:

- It ignores power differentials
- It strips away important context
- It assumes universal values across cultures
- It oversimplifies complex relationships

# Animal Rights Arguments: From Human to Non-Human

- Peter Singer's argument uses **analogical reasoning** to extend rights from humans to animals.
- Core analogy: If suffering matters morally for humans, it should matter for all sentient beings.
- The argument maps our obligations to vulnerable humans onto our treatment of animals.
- Critics challenge the analogy by pointing to cognitive differences and special human relationships.

## Example

Argument by analogy:

- We don't harm human infants (who lack full rationality)
- Adult pigs are more cognitively capable than human infants
- Therefore, the capacity difference doesn't justify harming pigs
- Conclusion: Species membership alone is arbitrary (speciesism)

# The Violinist Argument in Bioethics

- Judith Thomson's famous thought experiment uses **analogical reasoning** to examine abortion ethics.
- Scenario: You have been kidnapped by the Society of Music Lovers, and wake up connected to a famous unconscious (innocent) violinist who needs your kidneys for nine months.
- The analogy maps bodily autonomy rights from this case to specific pregnancy situations. perspective.

## Structure of the Argument

Violinist Case	Target Case
Kidnapped person	Pregnant woman
Unconscious violinist	Fetus
Life support connection	Pregnancy
Right to disconnect?	Right to terminate?

# Legal Precedent as Institutionalized Analogy

- The **common law system** operates through analogical reasoning from case to case.
- **Stare decisis** ("let the decision stand") requires treating like cases alike.
- Lawyers argue by showing similarities to favorable precedents and differences from unfavorable ones.
- This system embeds analogical reasoning into the fundamental structure of legal decision-making.

## Legal Reasoning Process

- 1 Identify relevant precedent cases
- 2 Extract the legal principle (ratio decidendi)
- 3 Map facts from precedent to current case
- 4 Apply the principle if facts are sufficiently similar

# The Art of Distinguishing Cases

- **Distinguishing** means showing why a precedent doesn't apply to the current case.
- Lawyers must identify legally relevant differences between cases.
- The skill lies in determining which factual differences actually matter for the legal principle.
- Judges must balance consistency with precedent against adapting to new circumstances.

## Example

A lawyer might distinguish cases by arguing:

- "In *Smith v. Jones*, the contract was verbal, but here it's written"
- This difference matters if the legal principle involves proof standards
- But wouldn't matter if the principle is about consideration

# Ratio Decidendi: Finding the Relevant Similarities

- **Ratio decidendi** is the legal principle that emerges from the essential facts of a case.
- Courts must determine which facts were crucial to the decision and which were incidental.
- Future cases are bound by the ratio, not by irrelevant details (**obiter dicta**).
- Different interpretations of the ratio lead to narrower or broader applications of precedent.

Precedent Case

Facts: A, B, C, D, E

Current Case

Facts: B, D, F, G

Ratio: B + D → Liability

Apply ratio? Yes



# Landmark Cases and Their Analogical Legacy

- **Landmark cases** establish principles that shape legal reasoning for generations.
- *Brown v. Board*: "Separate but equal" fails because segregation inherently implies inequality.
- *Miranda v. Arizona*: Custodial interrogation is inherently coercive without warnings.
- These cases become **source domains** for countless analogical arguments in new contexts.

## Extending Landmark Principles

*Brown's* equality principle has been analogically extended to:

- Gender discrimination in education
- Disability accommodations
- LGBTQ+ rights
- Each extension required arguing the analogy held

# When New Technology Challenges Old Analogies

- Legal systems struggle when **new technologies** don't fit existing analogical frameworks.
- Courts must decide: Is the internet like a newspaper, a broadcast, or something entirely new?
- Cryptocurrency challenges analogies: Is it property, currency, a security, or a new category?
- Poor analogical choices can lead to decades of problematic legal precedents.

## Example

Email privacy case:

- Is email like a sealed letter (strong protection)?
- Or like a postcard (limited protection)?
- Or like a phone call (context-dependent)?
- The chosen analogy shapes privacy rights

# How AI Systems Approach Pattern Matching

- AI systems find patterns through **statistical correlation** rather than causal understanding.
- Machine learning identifies similarities in high-dimensional feature spaces.
- Unlike humans, AI doesn't rely on **structural mapping** or understanding relationships.
- AI can detect patterns humans miss but also make errors humans would never make.

## AI vs Human Pattern Recognition

### Human Analogies

Causal understanding  
Structural alignment  
Context-sensitive  
Few examples needed

### AI Pattern Matching

Statistical correlation  
Feature similarity  
Context-agnostic  
Many examples needed

# Key Differences: Statistical Correlation vs. Causal Understanding

- Humans use analogies to infer **causal mechanisms** from one domain to another.
- AI systems find **correlational patterns** without understanding why they exist.
- This difference explains why AI can be fooled by adversarial examples that wouldn't confuse humans.
- Understanding this distinction helps us use AI appropriately and recognize its limitations.

Human

AI

Sees: Bird flies

Sees: Birds + flight co-occur

Infers: Wings cause flight

Learns: Feature correlation

Predicts: Planes need wings

Predicts: Feathers predict flight

# The Power and Peril of Thinking in Analogies

- Analogical reasoning is **fundamental** to human cognition and cultural progress.
- It enables us to leverage past experience, communicate abstract ideas, and make creative leaps.
- However, analogies can also constrain thinking, perpetuate biases, and mislead us.
- The key is developing **metacognitive awareness** about when and how we use analogies.

## Final Takeaways

- Recognize when you're reasoning by analogy
- Evaluate the structural mapping, not surface features
- Consider multiple analogies before committing
- Know when to abandon an analogy that no longer serves