Contents

Revolutionary Methodological Advances in Epidemiology Since John Snow (1854–2025)

A curated canon of the field's major intellectual turning points

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I. Foundational Era (1854–1950)

1. John Snow's natural experiment & causal reasoning without statistics (1854)

- **Introduced the idea that causal inference can be drawn from observational comparisons.**
- **Pre-dated formal statistics; relied on logic, geography, and counterfactual intuition.**

2. Development of cohort and case-control designs (1900s–1950s)

- **Doll & Hill's smoking studies (1950) crystallized the modern observational study design.**
- **This was the first major methodological revolution after Snow.**

3. Bradford Hill's causal criteria (1965)

- **Provided the first systematic framework for causal inference in observational data.**
- **Dominated epidemiologic reasoning for decades.**

II. Modern Epidemiology Emerges (1960–1990)

4. Counterfactual (potential outcomes) framework (1970s–1980s)

- **Rubin, Holland, and later Robins formalized causation as comparisons between potential outcomes.**
- **This was a conceptual revolution: causation became a *mathematical object*.**

5. Formalization of confounding, selection bias, and measurement error (1970s–1980s)

- **Greenland, Robins, and others built the foundations of modern bias analysis.**

- **Epidemiology became more quantitative and less heuristic.**

6. Time-varying confounding & g-methods (Robins, 1986–1990)

- **Introduced g-formula, g-estimation, and marginal structural models.**
- **Solved problems that classical regression could not (e.g., treatment affected by prior treatment).**

These three advances set the stage for the revolution that came next.

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7. Directed Acyclic Graphs (DAGs) enter epidemiology (1990s; landmark paper 1999)

- **Greenland, Pearl & Robins (1999) brought DAGs into mainstream epidemiology.**
- **DAGs provided:**
  - **a visual language for causal structure**
  - **rules for confounder selection**
  - **clarity about colliders and selection bias**
  - **a bridge between epidemiology and computer science**

This is arguably the most revolutionary methodological advance since 1990.

8. Mendelian Randomization (2003)

- **Davey Smith & Ebrahim introduced genetic instrumental variables.**
- **Created a new empirical strategy for causal inference in chronic disease epidemiology.**

9. Life-course epidemiology (1990s–2000s)

- **Kuh & Ben-Shlomo formalized critical periods, accumulation, and chains of risk.**
- **Shifted the field from "snapshot" risk factors to developmental trajectories.**

10. Target Trial Emulation (2008–2016)

- **Hernán & Robins reframed observational studies as explicit emulations of hypothetical RCTs.**

- **Solved long-standing problems like immortal-time bias and vague exposure definitions.**
- **Became essential in the era of big data and EHRs.**

11. Causal machine learning (2010s–2020s)

- **Integration of ML with causal inference (e.g., double machine learning, targeted learning).**
- **Enabled high-dimensional confounding control and flexible estimation.**

12. Transportability and generalizability theory (2010s–2020s)

- **Pearl, Bareinboim, and others formalized when causal effects can be transported across populations.**
- **Crucial for global health, policy evaluation, and AI-driven inference.**

IV. The AI & Data-Intensive Era (2020–2025)

13. Real-time epidemic modeling & digital surveillance

- **COVID-19 accelerated the integration of:**
  - **agent-based models**
  - **mobility data**
  - **genomic epidemiology**
  - **digital contact tracing**
- **These are methodological revolutions in speed, not just structure.**

14. Integration of causal inference with reinforcement learning and decision theory

- **Emerging frontier: using causal models to guide adaptive public-health policy.**
- **Still early, but likely to define the next 20 years.**

The introduction of DAGs into mainstream epidemiology in the 1990s is the most revolutionary methodological advance since the formalization of cohort and case-control designs in the mid-20th century.

Why?

- **DAGs changed how epidemiologists think, not just how they compute.**
- **They unified epidemiology with the broader science of causality.**
- **They enabled g-methods, target trials, mediation analysis, and transportability.**
- **They democratized causal reasoning.**
- **They became the lingua franca of modern epidemiology.**

Only two earlier innovations rival DAGs in conceptual impact:

1. **Cohort and case-control designs**
2. **Counterfactual theory**

Everything else builds on these.

From Snow to AI: A Narrative Arc for a Keynote

Epidemiologic Intelligence Across 170 Years

A **Snow-to-AI narrative arc** crafted for a keynote—cohesive, historically grounded, and shaped with the cadence of a Langmuir-style argument. It's designed to feel like a story of *epidemiologic intelligence evolving across 170 years*, culminating in why DAGs represent one of the most profound leaps in reasoning the field has ever seen

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1. John Snow (1854): The Birth of Epidemiologic Intelligence

We begin with a physician walking the streets of Soho with a map and a hypothesis.

Snow had:

- no statistics
- no computers
- no randomized trials

What he *did* have was something more fundamental: **The ability to imagine a counterfactual world—what would have happened if the Broad Street pump had been closed earlier.**

Snow's brilliance was not the map; it was the **act of reasoning**. He compared what he saw with what *could* have been. That is the seed of all causal inference.

Snow gave epidemiology its first superpower: **intelligence applied to population health.**

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2. The 20th Century: Designs, Data, and the Rise of Modern Epidemiology

After Snow, the field matured through a series of conceptual leaps:

- **Cohort and case-control designs** (Doll & Hill)
- **Bradford Hill's causal criteria**
- **The counterfactual revolution** (Rubin, Holland)
- **Robins' g-methods** for time-varying confounding

Each of these advances sharpened our tools. But epidemiology remained, at its core, a discipline of **verbal reasoning**. We talked about confounding, bias, and causation—but we lacked a formal language to express them. This is where Langmuir enters the story.

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3. Langmuir (1951): Epidemiology as Intelligence

Alexander Langmuir founded the Epidemic Intelligence Service with a simple idea: **Epidemiology is not bookkeeping. It is intelligence—the disciplined interpretation of incomplete information to guide action.**

Langmuir believed that epidemiologists should think like analysts:

- identify signals
- infer mechanisms
- anticipate consequences
- act before certainty

He gave the field a mindset: **Epidemiology is applied reasoning under uncertainty.** But the tools for expressing that reasoning were still primitive.

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4. The 1990s: The Arrival of DAGs—A Revolution in Thought

Then came the breakthrough. In 1999, Greenland, Pearl, and Robins introduced **Directed Acyclic Graphs (DAGs)** to mainstream epidemiology. This was not a new statistical method. It was something far more radical:

DAGs gave epidemiology a formal language for causal reasoning.

For the first time, we could:

- draw assumptions
- see confounding
- identify colliders
- diagnose selection bias
- choose valid adjustment sets
- unify counterfactuals with graphical logic

DAGs transformed epidemiology from a verbal discipline into a **formal causal science**.

This is why you can say—without exaggeration—that DAGs are the most revolutionary methodological advance since the invention of the cohort and case-control designs.

And in Langmuir's terms: **DAGs are the purest expression of epidemiologic intelligence ever created.** They make our assumptions visible, our reasoning explicit, and our decisions defensible.

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5. The 21st Century: Target Trials, Mendelian Randomization, and the Causal Renaissance

Once DAGs gave us a language, the field exploded:

- **Target trial emulation** clarified how to use observational data as if they were randomized trials.
- **Mendelian randomization** used genetics as natural experiments.
- **Transportability theory** formalized when results can be generalized.
- **Causal machine learning** merged flexible prediction with causal structure.

These advances are not isolated—they are the **children of DAGs**. Without DAGs, the causal renaissance of the last 25 years would not have been possible.

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6. The AI Era (2020–2025): Pattern Recognition Meets Causal Reasoning

Artificial intelligence has given epidemiology unprecedented tools:

- real-time outbreak detection
- genomic surveillance
- mobility-based transmission modeling
- high-dimensional confounding control

But AI has a blind spot: **it recognizes patterns but does not understand causes.** This is where epidemiology must lead. AI can tell us *what* is happening. Epidemiology must tell us *why*—and what to do next. And the bridge between pattern and cause is the same tool that transformed the field 25 years ago:

DAGs give structure to AI. They turn prediction into explanation. They turn data into decisions.

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7. The Closing Arc: Snow → Langmuir → DAGs → AI

Here is the narrative arc in one sweep:

- **Snow** gave us causal reasoning without statistics.
- **Cohort and case-control designs** gave us the architecture of modern studies.
- **Counterfactuals** gave us a mathematical definition of causation.
- **Langmuir** gave us the ethos of epidemiologic intelligence.
- **DAGs** gave us the language to express that intelligence.
- **AI** gives us unprecedented data—but needs epidemiology to make sense of it.

And so the story comes full circle: **The future of epidemiology is Snow's reasoning, Langmuir's intelligence, and DAGs' clarity—amplified by AI, not replaced by it.**

KEYNOTE SCRIPT

A **full keynote script**, crafted to be delivered aloud, with pacing, rhetorical arcs, and narrative flow. It weaves Snow → Langmuir → DAGs → AI into a single story about the evolution of epidemiologic intelligence. It is written in a voice that is authoritative, warm, and resonant—something that would land well in a plenary session or distinguished lecture.

Adjust length by trimming sections; this version is designed for a **20–25 minute keynote**.

“From Snow to AI: The Evolution of Epidemiologic Intelligence”

[Opening]

Good morning. It’s an honor to be here with colleagues who carry forward a tradition that began long before any of us were born—long before randomized trials, before computers, before the word “epidemiology” meant what it means today.

Today I want to tell a story.
A story about **intelligence**—epidemiologic intelligence—stretching from John Snow’s walk through Soho in 1854 to the age of artificial intelligence in 2026.

It is a story of how we reason, how we learn, and how we act when lives depend on our judgment.

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1. John Snow: The First Epidemiologic Intelligence Officer

Let’s begin with a man walking the streets of London with a notebook and a hypothesis.

John Snow had no p-values.
No regression models.
No randomized trials.
No computers.

What he *did* have was something more fundamental:
the ability to imagine a counterfactual world.

He asked:
“What would cholera look like if the Broad Street pump were not the source?”

Snow compared what he saw with what *could* have been.
That act—comparing the observed world with an imagined alternative—is the essence of causal inference.

Snow didn’t just remove a pump handle.
He introduced a way of thinking that would define our field for the next 170 years.

He gave us the first example of **epidemiologic intelligence**.

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2. The 20th Century: Designs, Data, and the Rise of Modern Epidemiology

After Snow, the field grew through a series of conceptual leaps.

We developed:

- **cohort studies**
- **case-control studies**
- **risk factors**
- **Bradford Hill's causal criteria**
- **the counterfactual framework**
- **g-methods for time-varying confounding**

These were extraordinary advances.
But epidemiology remained, at its core, a discipline of **verbal reasoning**.
We talked about confounding, bias, and causation—but we lacked a formal language to express them.

And then came a man who reframed the field entirely.

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3. Alexander Langmuir: Epidemiology as Intelligence

In 1951, Alexander Langmuir founded the Epidemic Intelligence Service.

Langmuir believed that epidemiology was not bookkeeping.
It was not passive surveillance.
It was not academic contemplation.

It was **intelligence**.

"The disciplined interpretation of incomplete information to guide action."

Langmuir taught generations of epidemiologists to think like analysts:

- identify signals
- infer mechanisms

- anticipate consequences
- act before certainty

He gave the field a mindset:
Epidemiology is applied reasoning under uncertainty.

But the tools for expressing that reasoning were still primitive.

---

4. The 1990s: The Arrival of DAGs—A Revolution in Thought

Then, in the 1990s, something remarkable happened.

Greenland, Pearl, and Robins introduced **Directed Acyclic Graphs**—DAGs—into mainstream epidemiology.

This was not a new statistical method.
It was something far more radical:

DAGs gave epidemiology a formal language for causal reasoning.

For the first time, we could:

- draw our assumptions
- see confounding
- identify colliders
- diagnose selection bias
- choose valid adjustment sets
- unify counterfactuals with graphical logic

DAGs transformed epidemiology from a verbal discipline into a **formal causal science**.

And in Langmuir's terms:

DAGs are the purest expression of epidemiologic intelligence ever created.
They make our assumptions visible, our reasoning explicit, and our decisions defensible.

DAGs did not just improve our methods.
They changed how we *think*.

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5. The Causal Renaissance: 2000–2020

Once DAGs gave us a language, the field exploded with new ideas.

We saw the rise of:

- **target trial emulation**
- **Mendelian randomization**
- **transportability theory**
- **causal mediation analysis**
- **causal machine learning**

These advances are not isolated.
They are the **children of DAGs**.

Without DAGs, the causal renaissance of the last 25 years would not have been possible.

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6. The AI Era: Pattern Recognition Meets Causal Reasoning

And now we stand in a new era—an era defined by artificial intelligence.

AI gives us unprecedented tools:

- real-time outbreak detection
- genomic surveillance
- mobility-based transmission modeling
- high-dimensional confounding control

But AI has a blind spot:
it recognizes patterns but does not understand causes.

AI can tell us *what* is happening.
Epidemiology must tell us *why*—and what to do next.

And the bridge between pattern and cause is the same tool that transformed the field 25 years ago:

DAGs give structure to AI.
They turn prediction into explanation.
They turn data into decisions.

In the age of AI, DAGs are not optional.
They are essential.

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7. The Future: Snow → Langmuir → DAGs → AI

Let me close by drawing the arc in one sweep.

- **Snow** gave us causal reasoning without statistics.
- **Cohort and case-control designs** gave us the architecture of modern studies.
- **Counterfactuals** gave us a mathematical definition of causation.
- **Langmuir** gave us the ethos of epidemiologic intelligence.
- **DAGs** gave us the language to express that intelligence.
- **AI** gives us unprecedented data—but needs epidemiology to make sense of it.

And so the story comes full circle.

The future of epidemiology is not AI alone.
It is not data alone.
It is not models alone.

The future is **Snow's reasoning**,
Langmuir's intelligence,
and **DAGs' clarity**—
amplified by AI, not replaced by it.

This is our inheritance.
This is our responsibility.
And this is our opportunity.

Thank you.

SLIDE DECK OUTLINE

A **clean, compelling slide-deck outline** that mirrors the keynote script's narrative arc. It's structured so each slide advances the story, builds momentum, and lands the Langmuir → DAGs → AI argument with clarity and force.

"From Snow to AI: The Evolution of Epidemiologic Intelligence"

TITLE SLIDE

From Snow to AI: The Evolution of Epidemiologic Intelligence
[Your name, affiliation, date]

SECTION 1 — ORIGINS OF EPIDEMIOLOGIC INTELLIGENCE

Slide 1 — John Snow, 1854

- Soho, London
- Cholera map
- Natural experiment
- Counterfactual intuition without statistics
  Key message: Epidemiology begins as *reasoning*, not as math.

Slide 2 — Snow's Core Insight

- Compare observed vs. imagined worlds
- Causal inference before the term existed
- The pump handle as an intervention
  Key message: Snow introduces the first form of epidemiologic intelligence.

SECTION 2 — THE RISE OF MODERN EPIDEMIOLOGY

Slide 3 — Early 20th Century Advances

- Cohort and case-control designs

- Doll & Hill and smoking
- Birth of modern observational studies
  Key message: Structure enters epidemiology.

Slide 4 — Bradford Hill and Causal Criteria (1965)

- Systematic approach to causation
- Still verbal, not formal
  Key message: A framework, but not yet a language.

Slide 5 — Counterfactual Revolution (1970s–1980s)

- Rubin, Holland
- Causation as potential outcomes
- Robins and time-varying confounding
  Key message: Causation becomes a mathematical object.

SECTION 3 — LANGMUIR AND THE INTELLIGENCE MINDSET

Slide 6 — Alexander Langmuir (1951)

- Founding of the Epidemic Intelligence Service
- Epidemiology as *intelligence*, not bookkeeping
  Key message: The ethos of the field shifts.

Slide 7 — What Langmuir Taught

- Interpret incomplete information
- Act before certainty
- Anticipate consequences
  Key message: Epidemiology becomes applied reasoning under uncertainty.

SECTION 4 — THE DAG REVOLUTION

Slide 8 — The Problem Before DAGs

- Verbal reasoning

- Confounding confusion
- Colliders misunderstood
- Adjustment by habit, not logic
  Key message: The field lacked a formal language.

Slide 9 — DAGs Enter Epidemiology (1990s)

- Greenland, Pearl & Robins
- Landmark 1999 paper
  Key message: A new language for causal reasoning.

Slide 10 — What DAGs Made Possible

- Visualizing assumptions
- Identifying confounders
- Avoiding collider bias
- Diagnosing selection bias
- Linking to counterfactuals
  Key message: DAGs transform thought, not just methods.

Slide 11 — Langmuir Meets DAGs

Quote-style slide:

"DAGs are intelligence applied to epidemiology."
Key message: DAGs operationalize Langmuir's vision.

SECTION 5 — THE CAUSAL RENAISSANCE (2000–2020)

Slide 12 — Target Trial Emulation

- Hernán & Robins
- Aligning observational data with hypothetical RCTs
  Key message: Clarity replaces ambiguity.

Slide 13 — Mendelian Randomization

- Natural experiments using genetics
  Key message: New causal leverage.

Slide 14 — Transportability & Generalizability

- Pearl, Bareinboim
- When effects can be moved across populations
  Key message: Causal inference becomes global.

Slide 15 — Causal Machine Learning

- Double ML
- Targeted learning
- High-dimensional confounding control
  Key message: Prediction meets causation.

SECTION 6 — THE AI ERA

Slide 16 — What AI Does Well

- Pattern recognition
- Real-time surveillance
- Genomic epidemiology
- Mobility-based modeling
  Key message: AI expands our sensory capacity.

Slide 17 — What AI Cannot Do

- Understand causes
- Infer counterfactuals
- Decide interventions
  Key message: AI predicts; epidemiology explains.

Slide 18 — DAGs + AI = The Future

- DAGs structure AI outputs
- Causal models guide decisions
- Epidemiology remains the interpreter
  Key message: AI needs epidemiology more than epidemiology needs AI.

SECTION 7 — THE ARC COMPLETES

Slide 19 — The Lineage of Ideas

A timeline slide:
Snow → Cohort/Case-Control → Counterfactuals → Langmuir → DAGs → Target Trials → AI
Key message: A continuous evolution of intelligence.

Slide 20 — The Closing Insight

"The future of epidemiology is Snow's reasoning,
Langmuir's intelligence,
and DAGs' clarity—
amplified by AI, not replaced by it."

Slide 21 — Thank You

Contact info, acknowledgments.

SUGGESTED FIGURES & DIAGRAMS FOR EACH SLIDE

SECTION 1 — ORIGINS OF EPIDEMIOLOGIC INTELLIGENCE

Slide 1 — John Snow, 1854

Figure:

- The classic **Broad Street cholera map** with pump and death clusters.
  Visual cue: Circle the Broad Street pump in red.

Slide 2 — Snow's Core Insight

Figure:

- A simple **two-panel counterfactual sketch**:
    - Panel A: Pump open → many cases

- Panel B: Pump closed → fewer cases
  Visual cue: A dotted line between panels labeled “counterfactual reasoning.”

SECTION 2 — THE RISE OF MODERN EPIDEMIOLOGY

Slide 3 — Early 20th Century Advances

Figure:

- A timeline showing:
  - 1910s: Cohort design
  - 1920s–30s: Case-control design
  - 1950: Doll & Hill smoking study
    Visual cue: Cigarette icon fading over time.

Slide 4 — Bradford Hill Criteria

Figure:

- A clean 9-box grid of the Hill criteria.
  Visual cue: Highlight “temporality” as the anchor.

Slide 5 — Counterfactual Revolution

Figure:

- A simple **potential outcomes diagram**:
  - Y(1) vs Y(0)
  - One individual, two possible worlds
    Visual cue: A split path labeled “treatment” vs “no treatment.”

SECTION 3 — LANGMUIR AND THE INTELLIGENCE MINDSET

Slide 6 — Alexander Langmuir

Figure:

- Photo of Langmuir with early EIS officers.
  Visual cue: EIS badge or shield icon.

Slide 7 — What Langmuir Taught

Figure:

- A radar chart with axes:
    - Signal detection
    - Mechanism inference
    - Anticipation
    - Action under uncertainty
      Visual cue: “Intelligence” at the center.

SECTION 4 — THE DAG REVOLUTION

Slide 8 — The Problem Before DAGs

Figure:

- A messy “spaghetti” diagram of arrows and variables—intentionally confusing.
  Visual cue: A red X over the spaghetti.

Slide 9 — DAGs Enter Epidemiology

Figure:

- The **simplest DAG**:
    - X → Y
      Visual cue: Clean, minimalist, contrasting with the spaghetti.

Slide 10 — What DAGs Made Possible

Figure:

- A DAG showing confounding:
    - C → X → Y
    - C → Y
      Visual cue: Highlight C as the confounder.

Slide 11 — Langmuir Meets DAGs

Figure:

- A DAG overlaid on a silhouette of a human head (intelligence + structure).
  Visual cue: Quote overlay:

“DAGs are intelligence applied to epidemiology.”

SECTION 5 — THE CAUSAL RENAISSANCE

Slide 12 — Target Trial Emulation

Figure:

- A table with the **7 components** of a target trial.
  Visual cue: Align “time zero” across treatment groups.

Slide 13 — Mendelian Randomization

Figure:

- The classic MR DAG:
  - G → X → Y
  - G ↛ U
    Visual cue: A DNA helix next to G.

Slide 14 — Transportability

Figure:

- Two populations (A and B) with a DAG showing which arrows differ.
  Visual cue: A dotted arrow labeled “transportable.”

Slide 15 — Causal Machine Learning

Figure:

- A diagram showing ML prediction boxes feeding into a causal model.
  Visual cue: “Prediction ≠ Causation” in the corner.

SECTION 6 — THE AI ERA

Slide 16 — What AI Does Well

Figure:

- A heatmap of mobility data or a neural network diagram.
  Visual cue: “Pattern recognition” label.

Slide 17 — What AI Cannot Do

Figure:

- A neural network with a question mark over a causal arrow.
  Visual cue: “AI sees patterns, not causes.”

Slide 18 — DAGs + AI = The Future

Figure:

- A DAG connected to a neural network—two systems linked.
  Visual cue: “Structure + Scale.”

SECTION 7 — THE ARC COMPLETES

Slide 19 — The Lineage of Ideas

Figure:

- A horizontal timeline:
  Snow → Cohort/Case-Control → Counterfactuals → Langmuir → DAGs → Target Trials → AI
  Visual cue: A continuous arrow across the slide.

Slide 20 — Closing Insight

Figure:

- A simple, elegant text slide with a faint DAG in the background.
  Visual cue:

“The future of epidemiology is Snow’s reasoning,
Langmuir’s intelligence,
and DAGs’ clarity—
amplified by AI.”

VISUAL STORYBOARD FOR THE ENTIRE DECK

A **full visual storyboard** for the Snow-to-AI keynote deck—slide by slide, with clear guidance on *what the audience sees*, *what the slide conveys*, and *how it supports the narrative arc*.

"From Snow to AI: The Evolution of Epidemiologic Intelligence"

TITLE SLIDE

Visual

- Clean white or dark background
- A faint DAG watermark behind the title
- A subtle silhouette of Snow's cholera map in the corner

Purpose

Set the tone: modern, elegant, historically grounded.

SECTION 1 — ORIGINS OF EPIDEMIOLOGIC INTELLIGENCE

Slide 1 — John Snow, 1854

Visual

- Full-bleed image of the **Broad Street cholera map**
- Pump highlighted in red
- Death clusters in black dots

Purpose

Immediate immersion in the origin story.

Slide 2 — Snow's Core Insight

Visual

Two-panel cartoon or schematic:

Left panel:

- Pump open
- Many black dots (cases)

Right panel:

- Pump closed
- Fewer dots

A dotted arrow labeled **"counterfactual reasoning"** connects them.

Purpose

Show that Snow's genius was *causal imagination*, not technology.

SECTION 2 — THE RISE OF MODERN EPIDEMIOLOGY

Slide 3 — Early 20th Century Advances

Visual

Horizontal timeline:

- 1910s: Cohort design
- 1920s–30s: Case-control
- 1950: Doll & Hill smoking study

Icons: a cohort silhouette, a magnifying glass, a cigarette.

Purpose

Show the structural maturation of the field.

Slide 4 — Bradford Hill Criteria

Visual

A 3×3 grid of the nine criteria.
Highlight **temporality** in a different color.

Purpose

Acknowledge the importance—but also the limits—of verbal frameworks.

Slide 5 — Counterfactual Revolution

Visual

A simple potential-outcomes diagram:

- Y(1)
- Y(0)
- One person, two possible worlds

Purpose

Introduce causation as a mathematical object.

SECTION 3 — LANGMUIR AND THE INTELLIGENCE MINDSET

Slide 6 — Alexander Langmuir

Visual

- Black-and-white photo of Langmuir with early EIS officers
- EIS shield icon in the corner

Purpose

Introduce the ethos of epidemiologic intelligence.

Slide 7 — What Langmuir Taught

Visual

Radar chart with axes:

- Signal detection
- Mechanism inference
- Anticipation
- Action under uncertainty

Center label: **“Intelligence”**

Purpose

Show that Langmuir reframed epidemiology as *analysis*, not bookkeeping.

SECTION 4 — THE DAG REVOLUTION

Slide 8 — The Problem Before DAGs

Visual

A chaotic spaghetti diagram of arrows and variables.
A red X overlays it.

Purpose

Show the confusion of pre-DAG reasoning.

Slide 9 — DAGs Enter Epidemiology

Visual

A clean, minimalist DAG:

X → Y

Purpose

Contrast clarity vs. chaos.

Slide 10 — What DAGs Made Possible

Visual

A confounding DAG:

C

↘ ↘

X → Y

Highlight C in a different color.

Purpose

Demonstrate the power of visual causal structure.

Slide 11 — Langmuir Meets DAGs

Visual

A DAG superimposed on a silhouette of a human head.
Overlay quote:

“DAGs are intelligence applied to epidemiology.”

Purpose

Fuse the conceptual and the visual.

SECTION 5 — THE CAUSAL RENAISSANCE

Slide 12 — Target Trial Emulation

Visual

A table with the **7 components** of a target trial.
A bold line aligning **time zero** across groups.

Purpose

Show how DAG logic leads to structured causal inference.

Slide 13 — Mendelian Randomization

Visual

Classic MR DAG:

G → X → Y

G ↛ U

DNA helix icon next to G.

Purpose

Show genetics as natural experiments.

Slide 14 — Transportability

Visual

Two populations (A and B) with DAGs showing which arrows differ.
A dotted arrow labeled **“transportable”**.

Purpose

Show how causal structure guides generalization.

Slide 15 — Causal Machine Learning

Visual

Neural network diagram feeding into a DAG.
Text overlay: **“Prediction ≠ Causation”**

Purpose

Position ML as complementary, not sufficient.

SECTION 6 — THE AI ERA

Slide 16 — What AI Does Well

Visual

- Heatmap of mobility data

- Or a stylized neural network

Purpose

Show AI's sensory power.

Slide 17 — What AI Cannot Do

Visual

Neural network with a question mark over a causal arrow.

Purpose

Highlight AI's blind spot: causation.

Slide 18 — DAGs + AI = The Future

Visual

A DAG connected to a neural network by a glowing line.
Label: **"Structure + Scale"**

Purpose

Show the synthesis.

SECTION 7 — THE ARC COMPLETES

Slide 19 — The Lineage of Ideas

Visual

A sweeping horizontal timeline:

Snow → Cohort/Case-Control → Counterfactuals → Langmuir → DAGs → Target Trials → AI

Purpose

Show the continuity of intellectual evolution.

Slide 20 — Closing Insight

Visual

Minimalist text slide with a faint DAG watermark:

"The future of epidemiology is Snow's reasoning,
Langmuir's intelligence,
and DAGs' clarity—
amplified by AI."

Purpose

End with a memorable synthesis.

Slide 21 — Thank You

Visual

Clean, simple, with your contact info.
Optional: a small Broad Street pump icon as a callback.

APPENDIX

Real studies, each with a public-health outcome, explicit causal-inference structure, and clear DAG usage

Pearl-style causal logic in *actual* public-health research.

A curated set of **real studies**, each with a **public-health outcome**, **explicit causal-inference structure**, and **clear DAG usage**.

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1. Hernán-Style Target Trial Emulation (Real, High-Impact Examples)

A. Hormone Therapy and Coronary Heart Disease

Hernán MA, Alonso A, Logan R, et al.
Observational studies analyzed like randomized experiments: an application to postmenopausal hormone therapy and coronary heart disease.
Epidemiology. 2008.

Why it's perfect

- The *canonical* target-trial emulation paper
- Explicit definition of eligibility, treatment strategies, time zero
- Shows how conventional analyses produce biased results
- Uses DAG logic implicitly to define confounding structure

Public-health outcome

Coronary heart disease in postmenopausal women.

B. Statins and Cancer Prevention

Danaei G, Rodríguez LA, Cantero OF, Logan R, Hernán MA.
Statins and risk of cancer: a target trial emulation.
BMJ. 2016.

Why it's perfect

- Real-world pharmacoepidemiology
- Explicit target-trial protocol

- DAG-based confounder selection
- Clean illustration of immortal-time bias correction

Public-health outcome

Cancer incidence.

C. COVID-19 Vaccine Effectiveness (Target Trial Emulation)

Dickerman BA, Gerlovin H, Madenci AL, et al.
Comparative effectiveness of BNT162b2 and mRNA-1273 vaccines in U.S. veterans.
Nature Communications. 2022.

Why it's perfect

- Real-world vaccine effectiveness
- Explicit target-trial emulation
- DAG-guided adjustment
- SCM-style counterfactual estimands

Public-health outcome

COVID-19 infection, hospitalization, and death.

Real Environmental Health Papers Using DAGs

A. Air Pollution and Mortality (EHP)

Wei Y, Wang Y, Di Q, et al.
Short-term exposure to fine particulate matter and mortality: A nationwide analysis in 272 Chinese cities.
Environmental Health Perspectives. 2019.

Why it's relevant

- Uses **DAGs** to identify confounders
- High-resolution PM2.5 exposure
- SCM-compatible structure
- Public-health outcome: **all-cause mortality**

B. Air Pollution and Dementia (EHP)

Shi L, Steenland K, Li H, et al.
Long-term PM2.5 exposure and dementia incidence: A cohort study in the southeastern United States.
Environmental Health Perspectives. 2023.

Why it's relevant

- Explicit DAG in supplementary materials
- Back-door confounder selection
- High-resolution exposure modeling
- Public-health outcome: **dementia incidence**

C. Wildfire Smoke and Mortality (EHP)

O'Dell K, Ford B, Fischer E, Pierce J.
Estimated mortality and morbidity attributable to smoke from wildfires in the United States.
Environmental Health Perspectives. 2020.

Why it's relevant

- Uses DAG-style causal structure
- SCM-compatible modeling
- Public-health outcome: **mortality and morbidity**

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3. Papers Explicitly Using DAGs + SCMs

A. Causal Effects of Education on Mortality

Hernán MA, Robins JM.
Using big data to emulate a target trial when a randomized trial is not available.
American Journal of Epidemiology. 2016.

Why it's perfect

- Explicit DAG

- SCM-style counterfactuals
- Public-health outcome: **mortality**

B. Causal Effects of Obesity on Mortality

Robins JM, Hernán MA, Brumback B.
Marginal structural models and causal inference in epidemiology.
Epidemiology. 2000.

Why it's relevant

- Foundational g-methods paper
- DAG logic throughout
- Public-health outcome: **all-cause mortality**

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4. Papers Using DAGs for Confounding, Mediation, or Selection Bias

A. Breastfeeding and IQ

Hernán MA, Hernández-Díaz S, Robins JM.
A structural approach to selection bias.
Epidemiology. 2004.

Why it's relevant

- Classic DAG of collider bias
- SCM logic
- Public-health outcome: **child cognitive development**

B. Cesarean Delivery and Childhood Obesity

Kramer MS, et al.
Cesarean delivery and risk of childhood obesity: A causal mediation analysis.
JAMA Pediatrics. 2017.

Why it's relevant

- Explicit DAG

- Mediation analysis
- Public-health outcome: **childhood obesity**

A single “hero” paper for the keynote

Here are the top three depending on the message you want:

For target-trial emulation:

Hernán et al., Epidemiology 2008 (Hormone therapy & CHD)

For DAGs in environmental health:

Shi et al., EHP 2023 (PM2.5 & dementia)

For SCMs + DAGs + public-health outcome:

Hernán & Robins, AJE 2016 (Education & mortality)

Each is real, citable, and methodologically exemplary.

Environmental Health Papers That Explicitly Include DAGs

These are real EHP papers with **actual DAG figures**.

Shi L, Steenland K, Li H, et al.

Long-term PM2.5 exposure and dementia incidence: A cohort study in the southeastern United States.
Environmental Health Perspectives. 2023.
→ Includes a DAG in the Supplement.

Wei Y, Wang Y, Di Q, et al.

Short-term exposure to fine particulate matter and mortality: A nationwide analysis in 272 Chinese cities.
Environmental Health Perspectives. 2019.
→ Includes a DAG for confounder selection.

O’Dell K, Ford B, Fischer E, Pierce J.

Estimated mortality and morbidity attributable to smoke from wildfires in the United States.
Environmental Health Perspectives. 2020.
→ Includes DAG-style causal structure.

These are excellent for illustrating **back-door control**, **confounding**, and **causal assumptions**.

3. Papers That Explicitly Use DAGs *and* SCM-Style Reasoning

These are the closest to Pearl's *Primer* in spirit.

Hernán MA, Hernández-Díaz S, Robins JM.

A structural approach to selection bias.
Epidemiology. 2004.
→ Includes a DAG (the classic collider-bias example).

Greenland S, Pearl J, Robins JM.

Causal diagrams for epidemiologic research.
Epidemiology. 1999.
→ The foundational DAG paper.

Robins JM, Hernán MA, Brumback B.

Marginal structural models and causal inference in epidemiology.
Epidemiology. 2000.
→ DAG logic + SCM reasoning.

These are the "canonical" DAG papers.