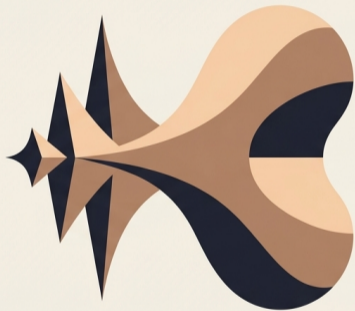


Resolution of Singularities

How Smoothing Mathematical
Rough Edges Powers Real-World
Breakthroughs



A Briefing for Policymakers

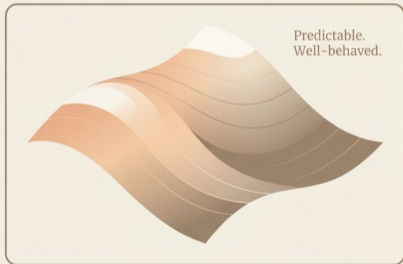
What if math could iron out the wrinkles in reality?



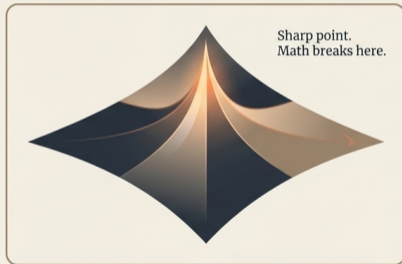
One mathematical idea connects them all.

A singularity is where smooth math breaks down

Smooth



Singular



Think: a smooth road vs. a pothole.

Singularities hide in plain sight

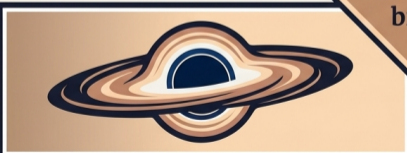


Lightning strike point

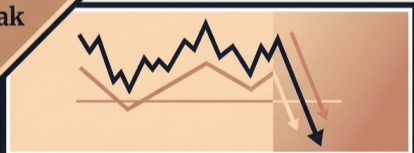


Dangerous road crossing

Where
the rules
break



Black hole center



Market crash moment

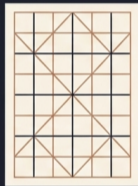
Resolution = uncrumpling the math



Crumpled
(Singular)



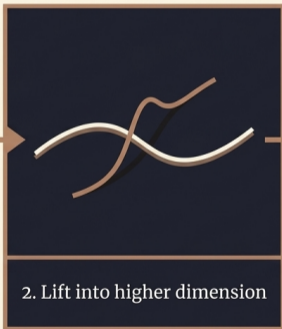
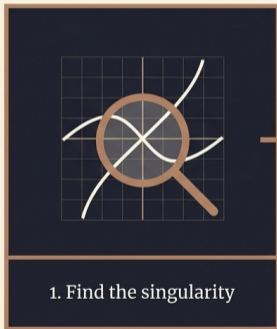
Unfolding
(Resolving)



Smooth
(Resolved)

The information was always there — resolution lets us read it.

Zoom in, lift up, smooth out



Like separating tangled headphone wires by pulling them apart in 3D.

Heisuke Hironaka proved it can always be done — in 1964



Fields Medal, 1970

“Any singularity in standard mathematics can be fully resolved into a smooth object.”

- Applies to **all dimensions** — curves, surfaces, and beyond
- One of the landmark theorems of 20th-century mathematics

This works in ‘characteristic zero’ — the math of everyday numbers.

Characteristic p : the unsolved frontier that powers your phone

Characteristic Zero (Solved ✓)

$$1 + 1 = 2$$

$$5 + 5 = 10$$

Numbers work as expected



Characteristic p (Unsolved ✗)

In char. 2: $1 + 1 = 0$

In char. 3: $2 + 2 = 1$

Clock arithmetic — numbers wrap around



Characteristic p **arithmetic** is the foundation of modern **encryption**, **error-correcting codes**, and secure **communications**. Resolution of **singularities** here remains **UNSOLVED** — one of **math's great open problems**.

01

Stronger encryption starts with smoother math

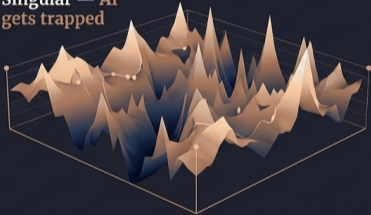


- **Elliptic curve** cryptography relies on **algebraic geometry** — singularities weaken the math
- Resolving singularities in characteristic p hardens encryption against quantum attacks
- **Protects:** banking, defense communications, personal data

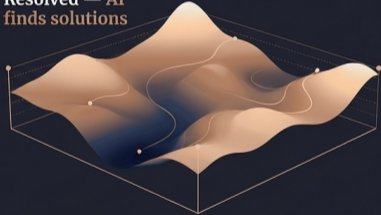
\$10.5 trillion — estimated global cost of cybercrime by 2025 (Cybersecurity Ventures)

02 AI learns faster when the landscape is smooth

Singular — AI gets trapped



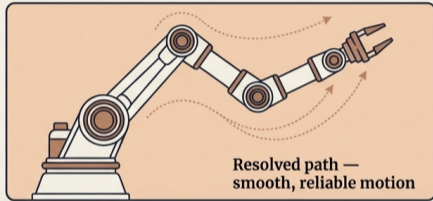
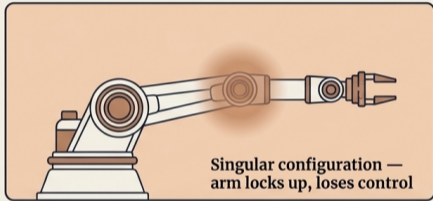
Resolved — AI finds solutions



- Neural network training landscapes are full of singularities
- Singular learning theory uses resolution of singularities to explain why deep learning works

Directly improves: autonomous vehicles, medical diagnostics, language models

03 Robots navigate the world by resolving singularities

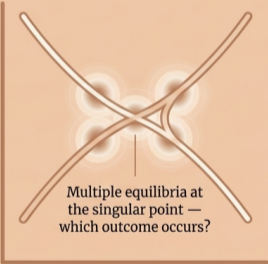


- Robot joint configurations create geometric spaces with singularities
- Surgical robots, factory arms, and drones must avoid singular configurations
- Resolution theory maps all dangerous configurations in advance

\$73 billion — global industrial robotics market by 2029

04

Economic models fail at singularities — and so does policy



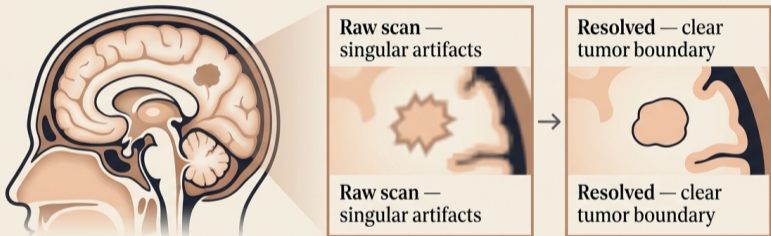
Multiple equilibria at the singular point — which outcome occurs?

- Market equilibrium models break down at singular points
- Trade policy, tax reform, and regulatory impact models all face this
- Resolution techniques help economists identify stable vs. unstable outcomes
- Better models = better policy decisions

The 2008 financial crisis exposed singular failure points in risk models.

05

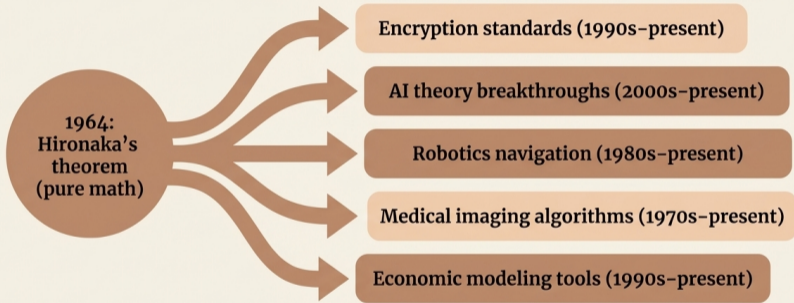
Medical imaging reconstructs the body by resolving singularities



- CT and MRI reconstruction algorithms encounter mathematical singularities
- Resolution techniques sharpen boundaries between healthy and diseased tissue
- Also used in: drug molecule modeling, protein folding, genomic data analysis

Early detection of a tumor can improve 5-year survival by 50%+.

Basic math research delivers outsized economic returns



Every \$1 invested in basic math research returns \$10–\$20 in downstream economic value.

(OECD Science & Technology Indicators)

Fund the math that funds everything else.

Support sustained public investment in foundational mathematics research.

1. Maintain and increase grants for pure mathematics through national science agencies
2. Fund dedicated programs for the characteristic p resolution problem
3. Build bridges between mathematicians and applied sectors — defense, health, finance