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BROAD INSTITUTE

Biological Attribution:

Bridging the Detection-Attribution Gap

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The Uncomfortable Truth

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We Excel At

- Detecting disease outbreaks within days
- Sequencing pathogens within hours
- Modeling spread in real-time
- Implementing control measures

We Fail At

Who did this?

The question law enforcement needs answered

A Challenging Pattern

> *"The actual introduction pathway was not identified."*

This phrase appears with regularity

Even when scientific evidence suggests external introduction and epidemiological patterns rule out natural spread

Two Different Paradigms

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DETECTION

Epidemiological Questions

- Is there disease?
- Where is it spreading?
- What pathogen?
- How fast?

Follows the logic of pathogens

ATTRIBUTION

Forensic Questions

- How did this start?
- Natural or deliberate?
- Who had capability?
- Who had motive?

Follows the logic of human actors

Different Spaces, Different Data

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Detection Surveillance

Maps biological space

- Transmission chains
- Risk factors for spread
- Pathogen distribution
- Host susceptibility

Attribution Surveillance

Maps behavioral & economic space

- Supply chain movements
- Financial transactions
- Pattern deviations
- Human decision points

These patterns look different… if you know what to look for and collect the right data from the beginning

The Fundamental Problem

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Detection Surveillance

REACTIVE

We start collecting samples after we know there's disease

Attribution Surveillance

PROACTIVE

Samples and data must be collected continuously, before we know they'll matter

This requires completely different infrastructure, protocols, and funding models

What We're Missing

If we only collect detection samples from sick animals...

- ❌ No baseline samples from before the outbreak
- ❌ No environmental samples or chain-of-custody documentation
- ❌ No metadata about unusual purchases or behaviours

All of this must be collected in real-time, before we know it will matter

PART 2

Negative Space Forensics

Looking at What's Absent, Not Just What's Present

A Fundamental Inversion

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Traditional Forensics

Look at what happened

- Where did the crime occur?
- What evidence is present?
- Who was there?

Positive evidence—what's there

Negative Space Forensics

Look at what didn't happen

- What's missing that should be there?
- What didn't happen that should have?
- Where is the silence?

Absence as evidence

PATTERN 1

The "Too Clean" Signal

Natural Outbreaks

Messy

- Mixed infections
- Co-pathogens present
- Genetic diversity
- Environmental contaminants
- Evidence of ecological journey

Deliberate Releases

Suspiciously Pure

- Laboratory monoculture
- Absence of co-pathogens
- Too homogeneous
- Lack of genetic drift
- No ecological complexity

Requires metagenomic surveillance—not just targeted diagnostics

PATTERN 2

Epidemiological Silence Mapping

Perpetrators leave traces in where disease doesn't appear

Safe Zones = Human Intelligence

- High-risk sentinel farms remain clean while lower-risk farms get infected
- Geographic patterns that follow political boundaries, not ecological ones
- Areas avoided due to economic interests or confederate protection

PATTERN 3

Strategic Logic Fingerprint

Pathogen Optimization

Driven by biological opportunity

- Suitable hosts
- Favourable weather
- Dense populations
- Transmission conditions

Human Optimization

Driven by strategic objectives

- Economic damage
- Political timing
- Symbolic targeting
- Trade disruption

Why this target? Why this pathogen? Why this timing? The answers reveal strategic thinking.

PATTERN 4

Behavioral Counterfactuals

Foreknowledge creates behavioral anomalies

Actions that only make sense if someone knew what was coming:

- Unusual insurance purchases
- Strategic animal movements
- Obscure vet consultations
- Workers quitting suddenly
- Supplier withdrawals

The behavioral equivalent of insider trading

PART 3

Multi-Layered Attribution

Outbreak Investigation Through Multi-Layer Evidence

Multi-Layered Attribution

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Digital Twin Epidemiology

Statistical simulation of disease spread patterns

Network Analysis

Graph theory to detect anomalous transmission

Forensic Phylodynamics

Genomic evidence of pathogen origin

Environmental DNA

Trace evidence linking to geographic origin

Method 1: Digital Twin Epidemiology

The Concept

Create virtual replica of agricultural system and simulate disease spread under natural conditions.

10,000+ simulations

Monte Carlo modeling

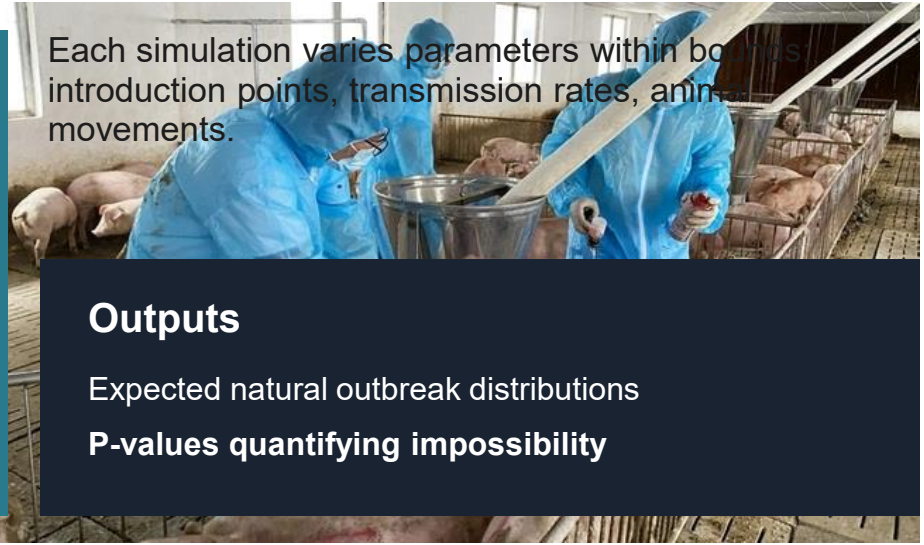
Case Study: African Swine Fever - Europe 2024

The Anomaly

ASF appeared 250 miles from nearest infection with no intermediate cases

Model Inputs

- Geography & farm densities
- Animal movement networks
- Wild animal ecology
- Biosecurity & climate factors



Each simulation varies parameters within bounds: introduction points, transmission rates, animal movements.

Outputs

Expected natural outbreak distributions

P-values quantifying impossibility

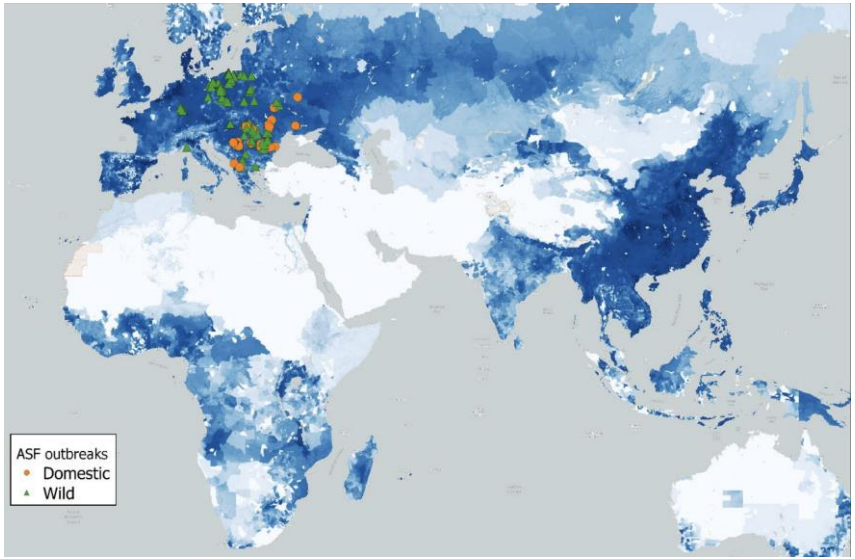
Case Study: African Swine Fever - Europe 2024

The Anomaly

ASF appeared 250 miles from nearest infection with no intermediate cases

Overlay the real outbreak data on the simulated distribution.

Where does it fall?



WOAH, 2024
(Situation Report 60)

Case Study: African Swine Fever - Europe 2024

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The Anomaly

ASF appeared 250 miles from nearest infection with no intermediate cases

Simulation Results

$p < 0.001$

Less than 0.1% probability in simulations

Conclusion

Statistical evidence of human-mediated spread through deliberate or accidental introduction

Method 2: Networks

A

Natural Outbreak Pattern

Transmission Chain:

- Power-law degree distribution
- Super-spreader events (few hubs)
- High clustering coefficient
- Branching chains grow gradually
- Local transmission clusters

0.1 substitutions/site

Sparse network with hubs

B

Deliberate Point-Source Pattern

Star Topology:

- Single central source node
- Many simultaneous initial cases
- Low clustering (unclustered)
- Cases appear independently
- No farm-to-farm transmission

0.01 substitutions/site

Star: central hub, many spokes

Method 3: Forensic Phylogeny

The Molecular Clock as Detective

Genomic sequencing identifies pathogen evolution and origin through mutation patterns

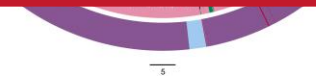
What It Reveals

- Low diversity = recent single introduction
- Strain matches foreign source, not local
- Evolutionary tree incompatible with natural spread
- Direct link to suspected origin country

Evidence Type

Phylogenetic trees show if outbreak strain is native or imported from external source

Example: Wheat Blast in Bangladesh nearly identical to South American lineage, not Asian.



Method 4: Environmental DNA

The Hitchhikers

Pathogen samples contain microbial fingerprints from their origin environment

Key Finding

Co-occurring microbes link pathogen to specific geographic regions or soil types

Analysis Process

- Metagenomic sequencing of sample
- Identify co-occurring microbes
- Match to geographic databases
- Triangulate likely origin

Multi-Layered Attribution

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Digital Twin

$p < 0.001$ for 250-mile jump

Network Analysis

Star topology

Phylodynamics

External strain, not local evolution

eDNA Analysis

Microbiome signature from origin

Converging Evidence = High Confidence Attribution

All four methods point to deliberate or human-mediated introduction

PART 4

The Silent Attribution Problem

Why Cases Go Unsolved

The Pattern You'll Recognise

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- ✓ Exotic strain appears in disease-free region
- ✓ Molecular analysis confirms external introduction
- ✓ Genome matches distant region—unlikely natural emergence
- ✓ Investigation narrows down origin to specific farms

Then... the investigation stops

Why Attribution Fails

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Trade Implications

Export bans, market restrictions, retaliatory responses

Liability Cascade

Years of litigation, diplomatic tensions, agency challenges exposed

Retaliation Risk

National security implications, intelligence fallout, escalation

Market Panic

Consumer confidence drops, insurance spikes, market access lost

Result: We have the tools to know. Sometimes we choose not to tell.

The Insider Threat Paradox

The people most likely to commit these crimes are the same people we depend on for detection

Typical Perpetrator Profile:

- Disgruntled employees
- Economic saboteurs
- Activists
- Proxies

You can't investigate without your detection network. But your detection network includes your suspects.

The Path Forward

We need parallel attribution surveillance infrastructure

Independent of detection networks

Forensic capacity separate from diagnostic capacity

Can't treat every partner as a suspect—but can't ignore the insider threat either

Engaging Law Enforcement

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OLD FRAME

Agricultural compliance issue

Regulatory problem

Technical incident

Low priority for law enforcement

NEW FRAME

Organised crime

Terrorist financing

National security threat

Biological weapons deployed for profit

Organised Crime Nexus

€40B

Annual food fraud industry

INTERPOL estimate

$15B+

Livestock smuggling market

Existing Tools Apply

- Statutes for patterns of criminal activity
- Asset forfeiture laws
- Surveillance authority
- International trafficking frameworks

Law enforcement already has the legal tools

INTERPOL

OPERATION PANGEA XVII

Targeting the online sale of illicit pharmaceuticals

90
Countries involved

847
Search warrants issued

123
Criminal groups dismantled

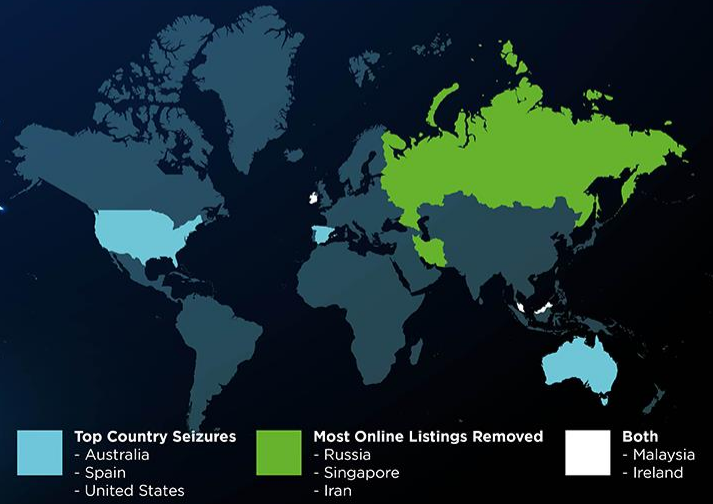
50.4 million
doses seized

1,728
Investigations conducted

769
Individuals arrested

USD 65 million
Estimated value

Breakdown of product seizures



UK National Wildlife Crime Unit

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Structure

- Upskilled officers with forensics training
- Partnership with NGOs (WWF, RSPB)
- Intelligence-led policing
- Annual budget: ~£424,000 (2024-25)

uk|NWCU
uk|National Wildlife Crime Unit

£600,000

Confiscation order for destroying a bat roost – the largest wildlife-crime fine in UK history.

£71,000 confiscation for illegal trade in endangered species.

£61,000 confiscation order for ivory trading offences.

Proof of Concept
Small specialist units outperform generalists

Deterrence Through Attribution

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Without attribution, deliberate biological attacks remain low-risk, high-reward strategies

Current State

- Incomplete attribution capability
- Rarely communicate capabilities
- Weak prosecution track record

Result: Minimal risk perception

Required for Deterrence

- Build attribution capability
- Communicate capability
- Demonstrate willingness to use it

Result: Changed risk calculus

Every successful unattributed attack emboldens future perpetrators

World Organisation for Animal Health

Thank you

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