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Modelling for Informing Policy Development: Constraints and Challenges

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Outline

- context
- policy development
- modelling
- validity und uncertainty
- examples
- conclusions

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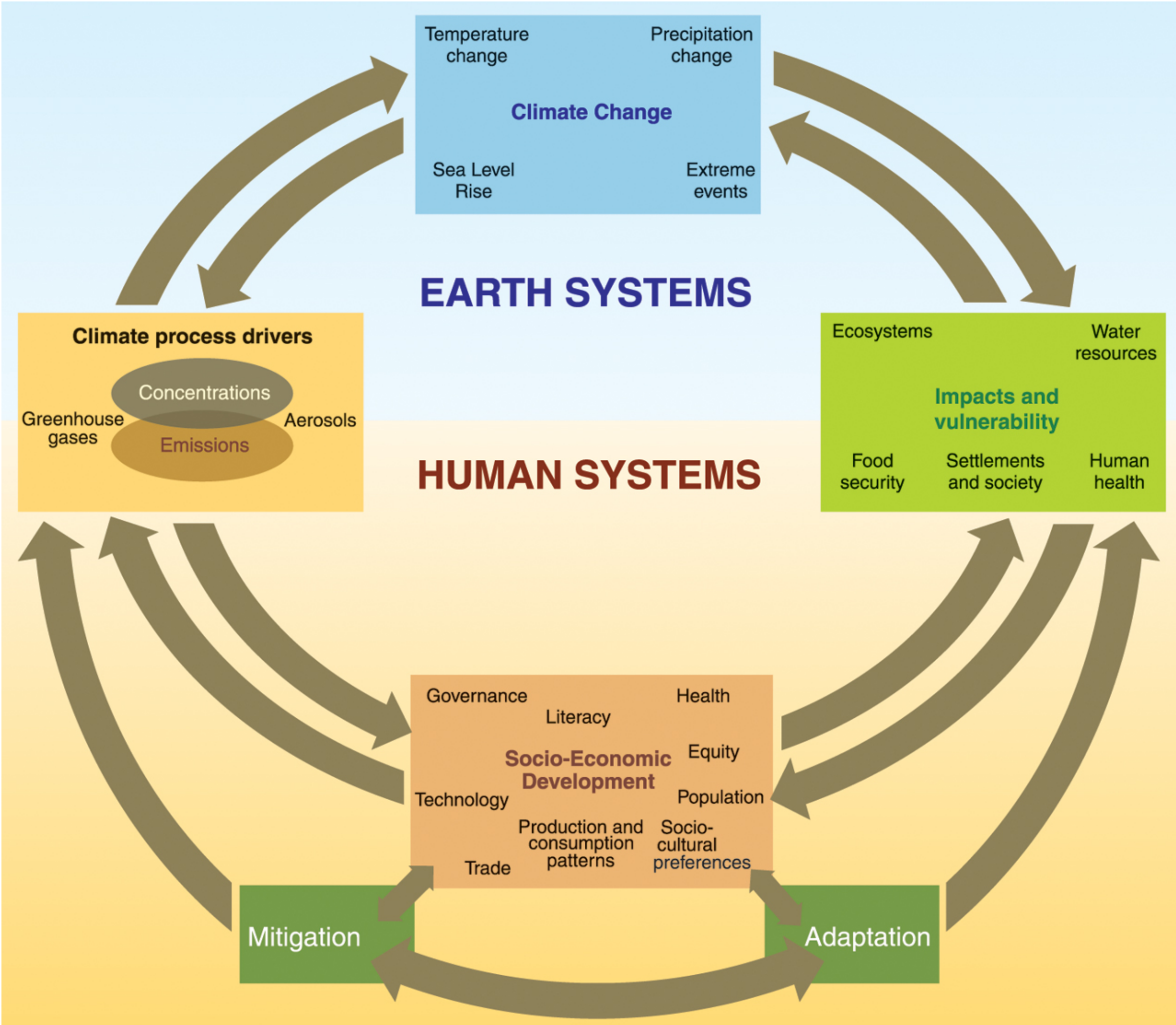
Thinking about the Future

- need to be able to handle
  - o uncertainty
  - o complexity
  - o multiple plausible futures
- approaches
  - o narratives
  - o group processes
    - Delphi -> consensus-based response
    - Foresight -> focus on deliberations
  - o modelling

Climate Change



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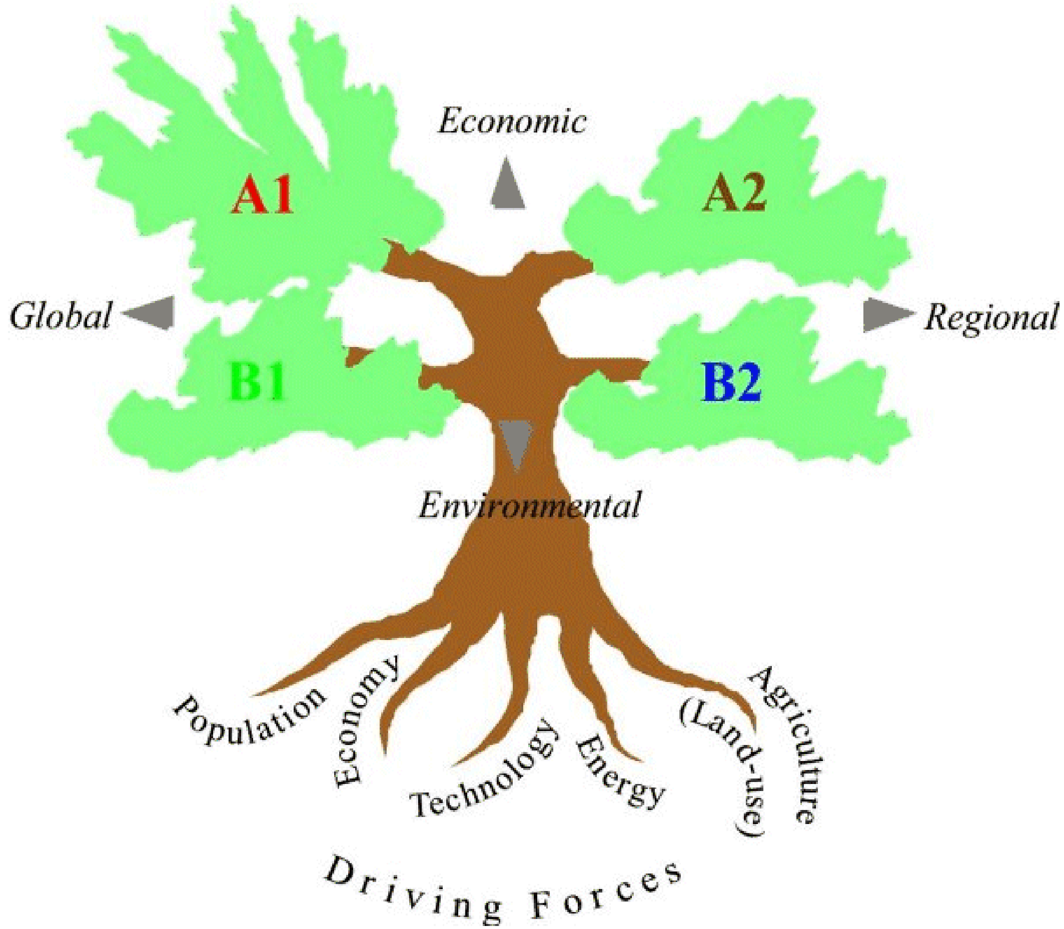
Source: IPCC 2007

Scenarios Modelled by Intergovernmental Panel on Climate Change (IPCC)



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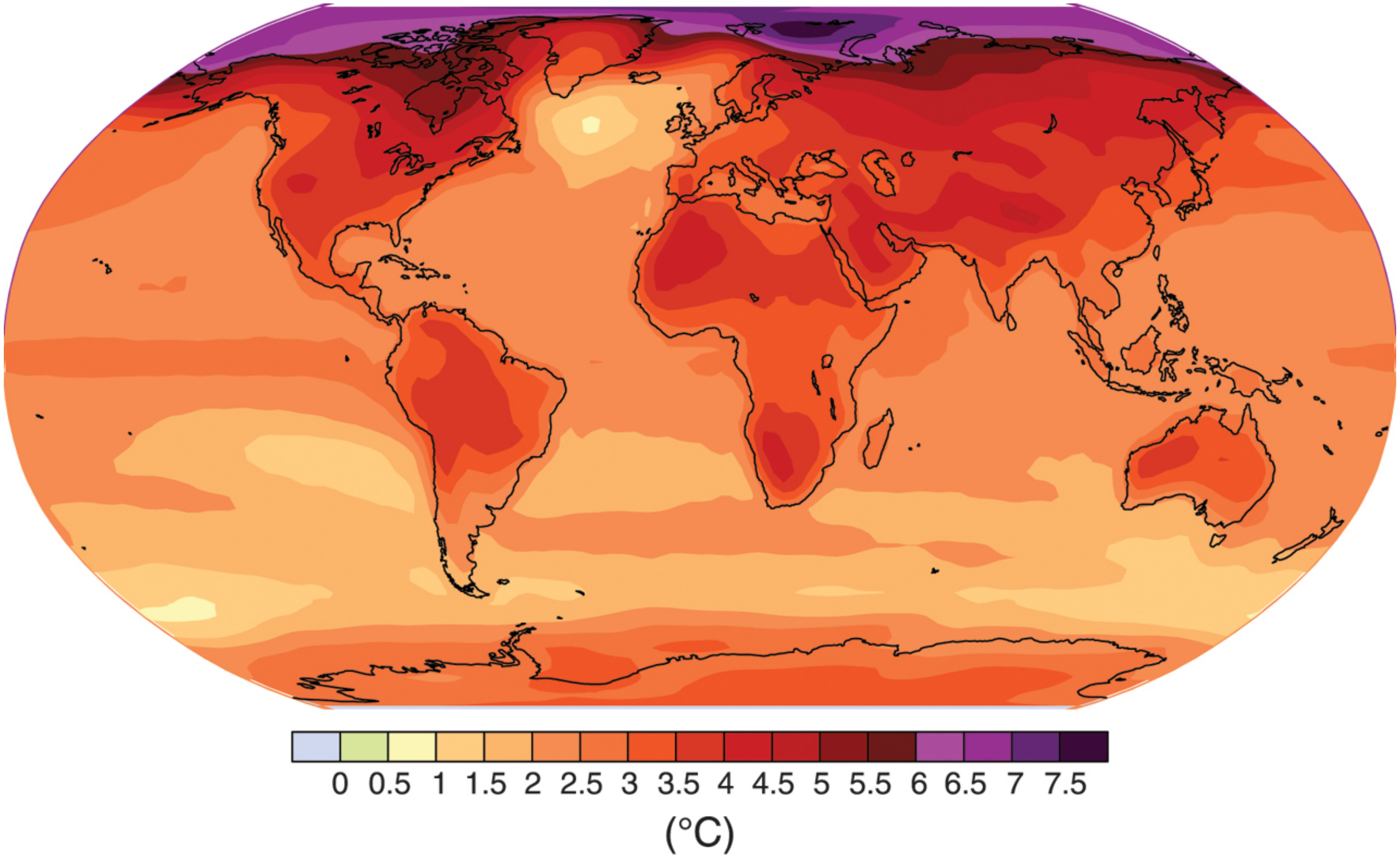
Projected Temperature Change for 2090-99 (relative to 1980-1999)



Source: IPCC 2007

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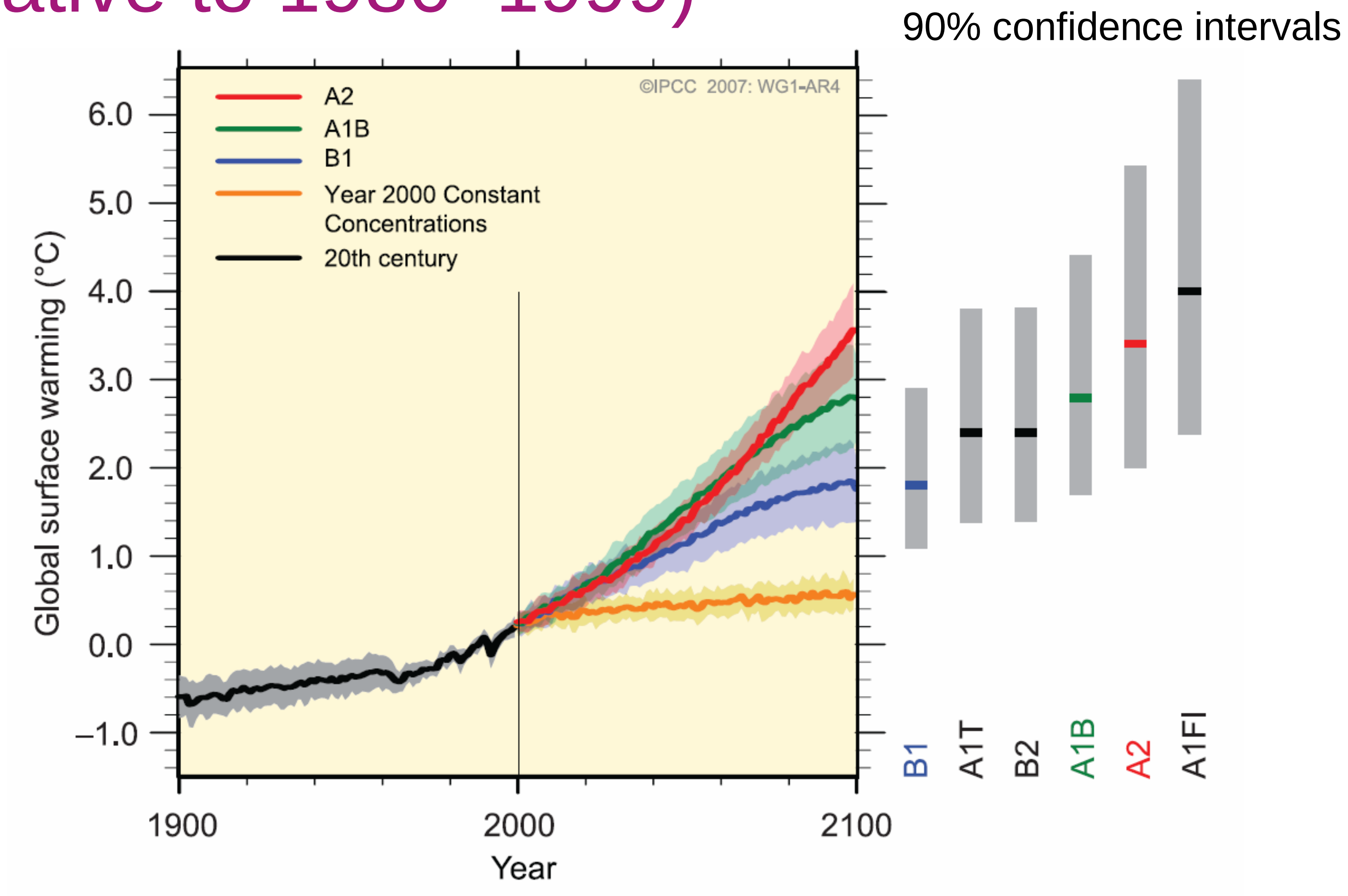
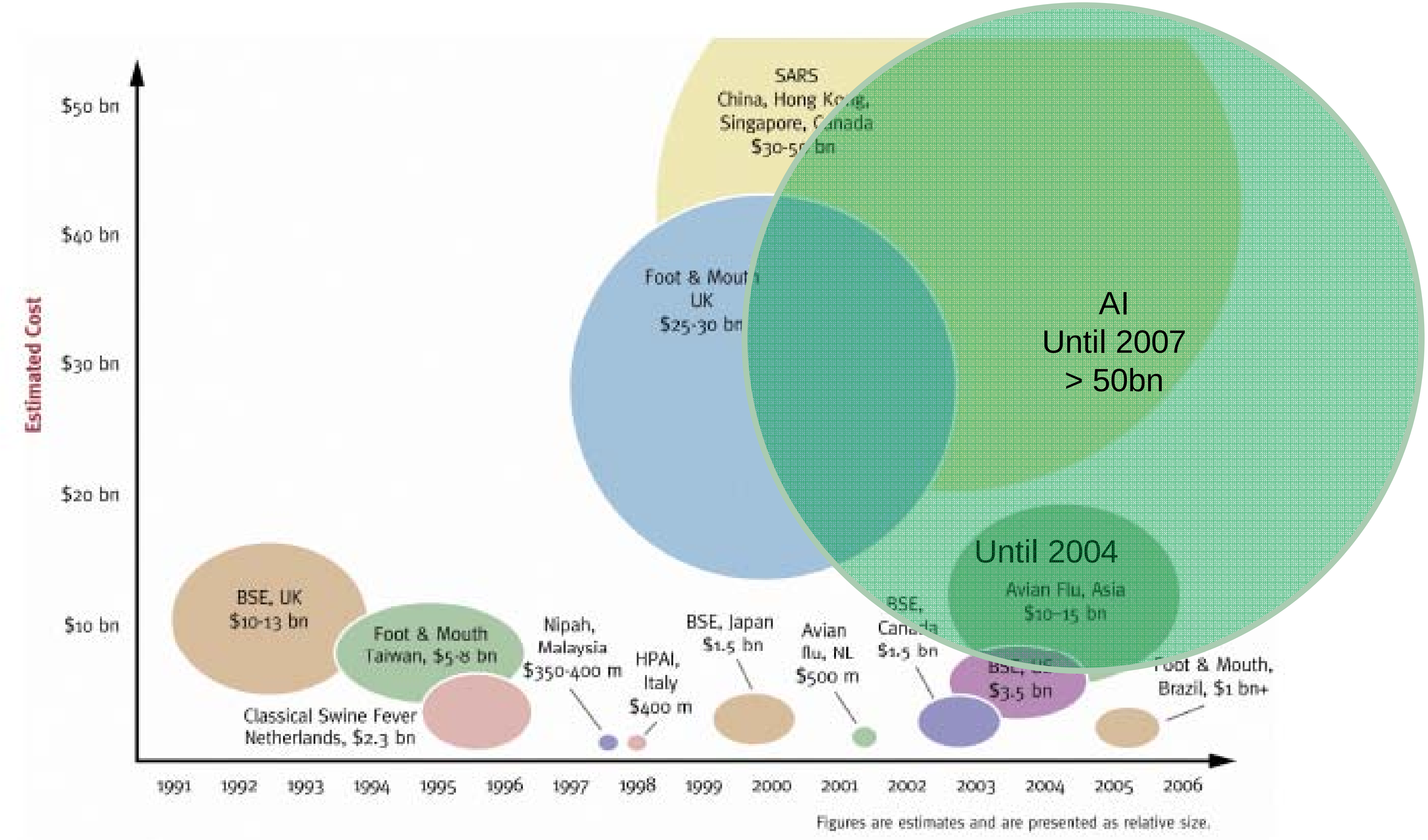
Model Predictions of Multi-Model Global Averages of Surface Warming (relative to 1980–1999)



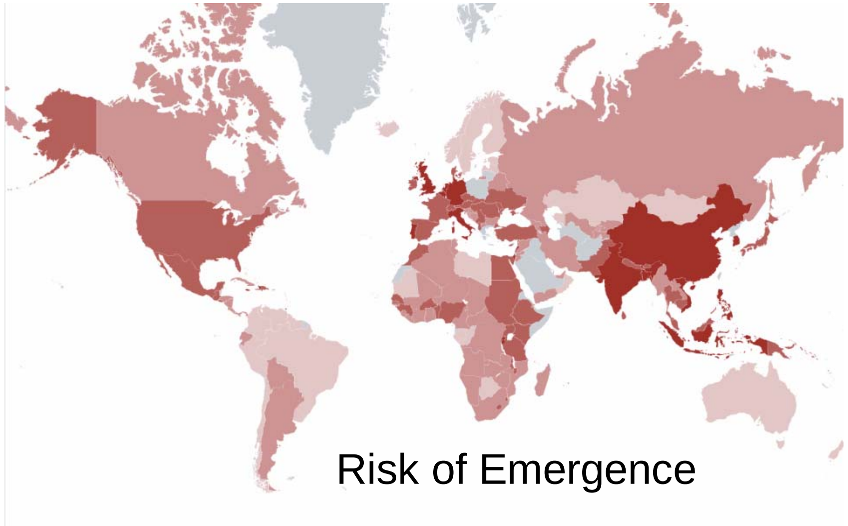
Source: IPCC 2007

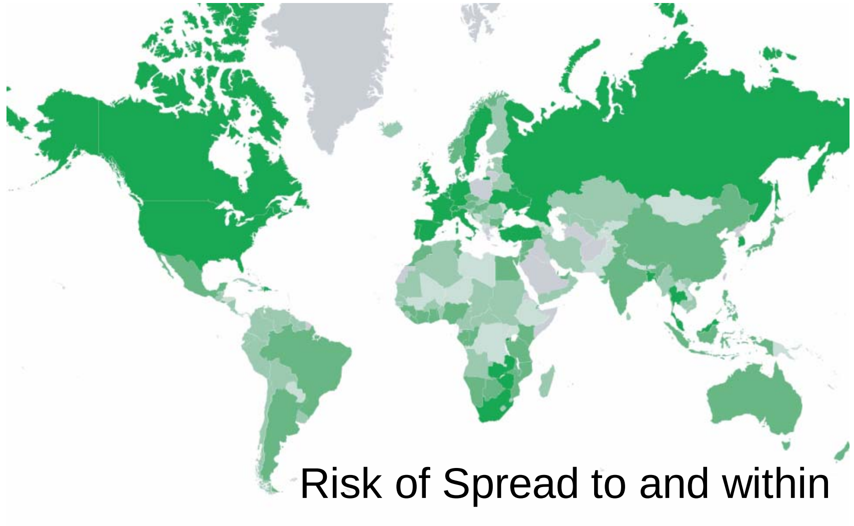
Costs of Animal Disease Outbreaks

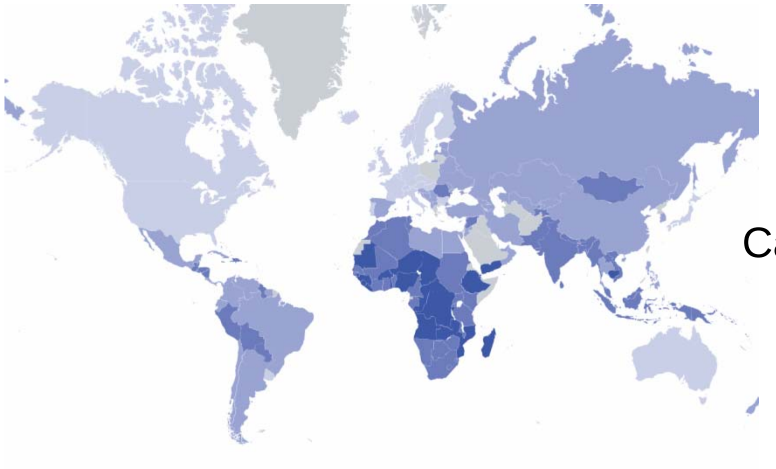


Source: Bio Economic Research Associates paper on the *Economic Risks Associated with an Influenza Pandemic*, presented to the United States Senate Committee on Foreign Relations, November 9, 2005

Global Risk of AI Pandemic







Capacity to Contain

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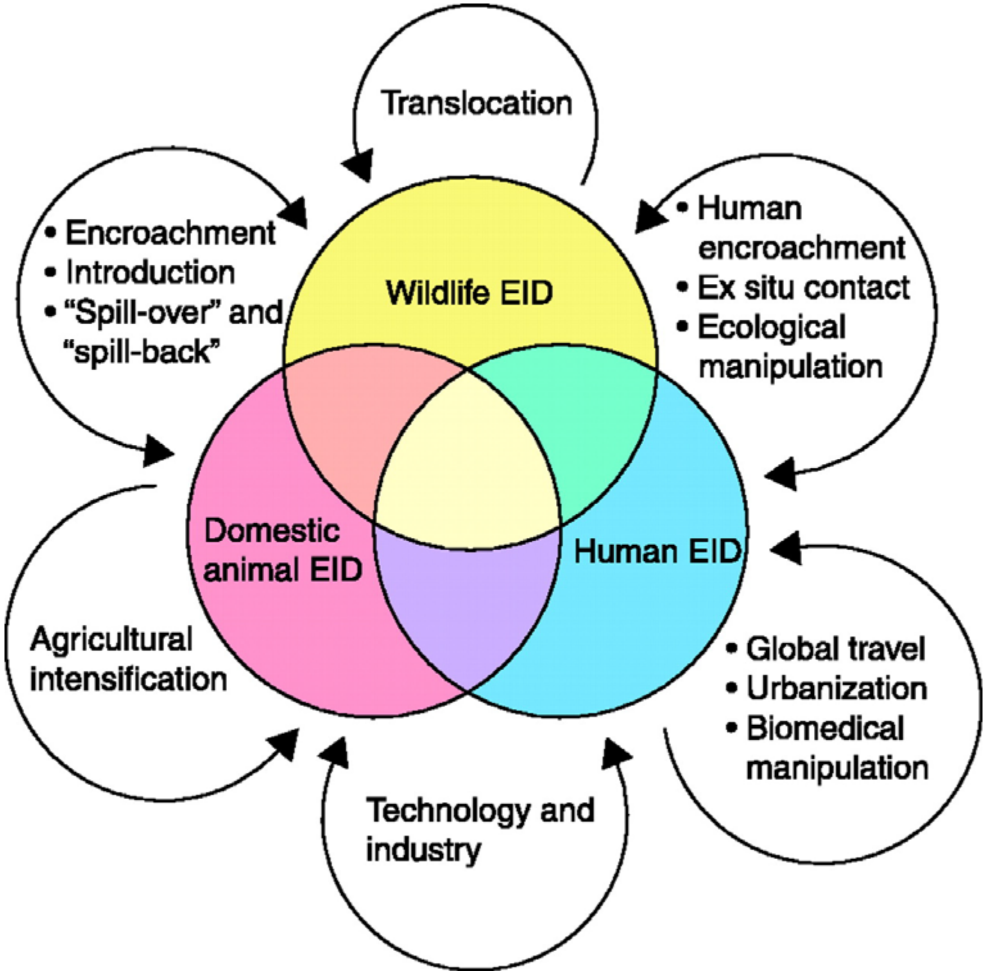
From maps.maplecroft.net

Host-Parasite Ecological Continuum



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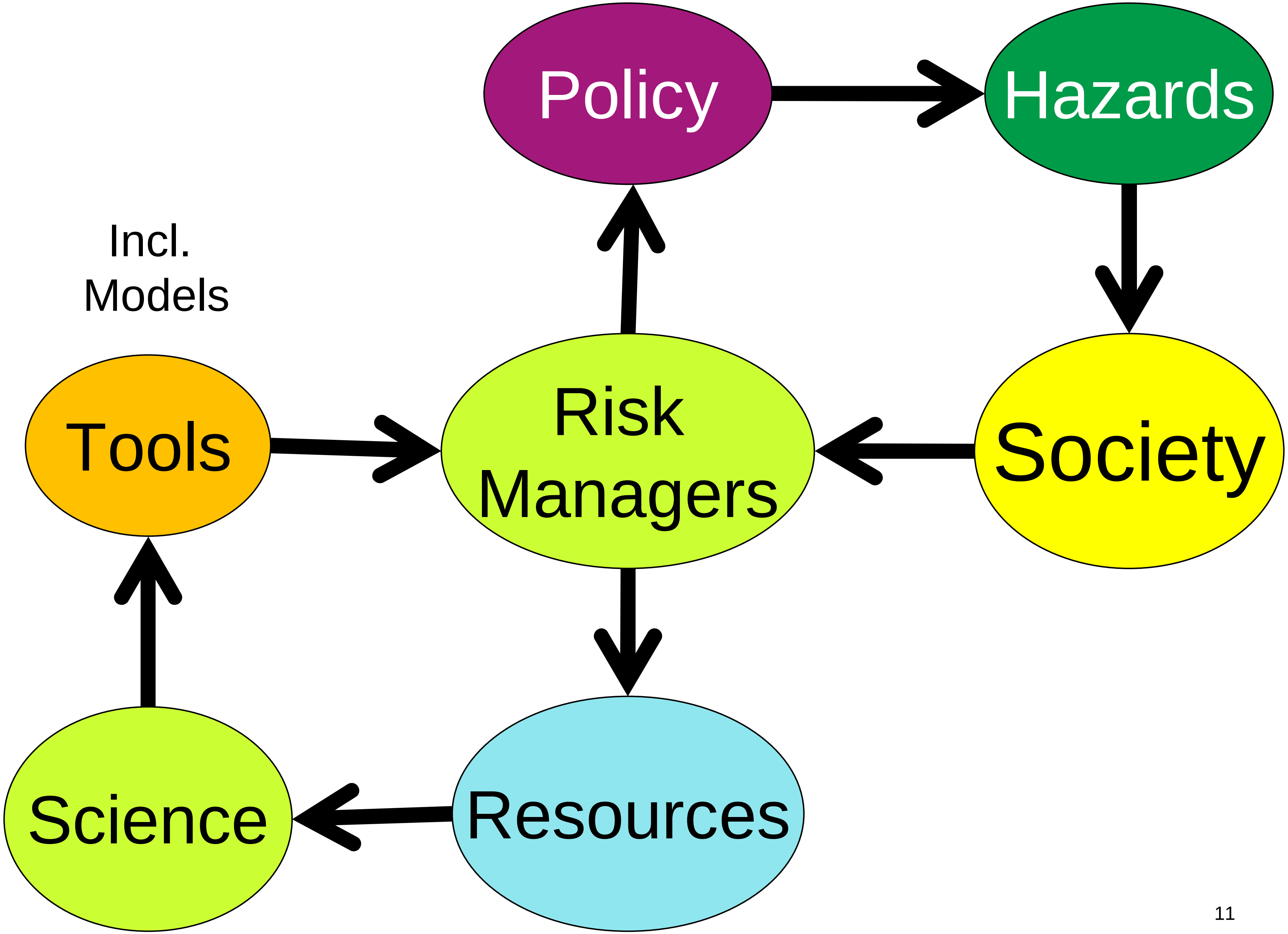
From Daszak et al. 2000: *Science*


Policy
Hazards
Incl.
Models
Tools
Risk
Managers
Society
Science
Resources

Disease Control Policy

- disease control policy informed by understanding of cause-effect relationships
  - o experience and judgment
  - o scientific explanations / predictions
    - risks and uncertainty
- success of disease control programmes influenced by commitment of stakeholders towards programme goals
  - o perceptions in relation to validity and relevance of cause-effect relationships

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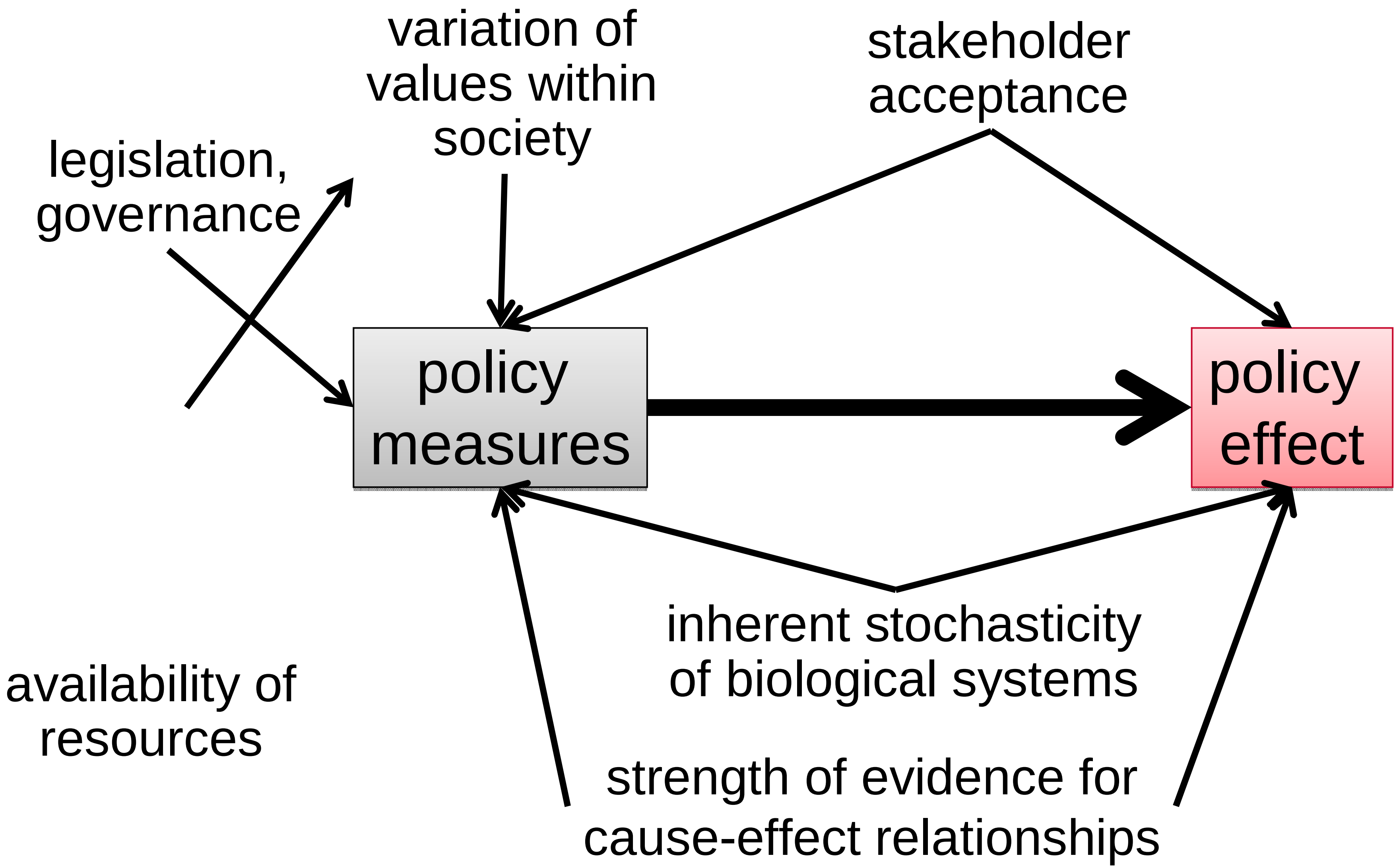
Disease Control Policy *cont.*

- ‘knowledge-based’ society requires extensive consultation and debate about approaches, progress and outcomes
  - o effective communication becomes integral component of disease control programme
  - o participatory approaches

Policy Development, Implementation and Impact



Policy Development and Communication

- communicate risks and uncertainty in relation to likelihood of possible outcomes of policy implementation to stakeholders
  - o generally recognised reduction of public trust in science
  - o influenced by risk perception, education and effectiveness of risk communication strategy

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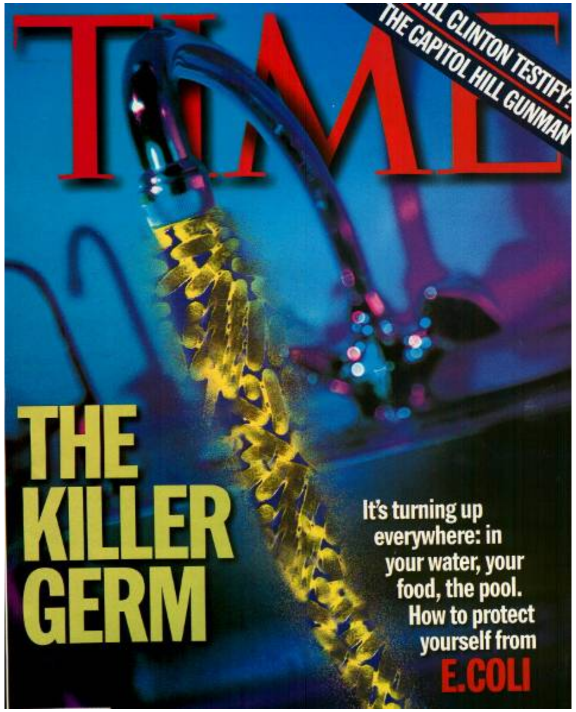



HEALTH

The Revenge Of the Birds

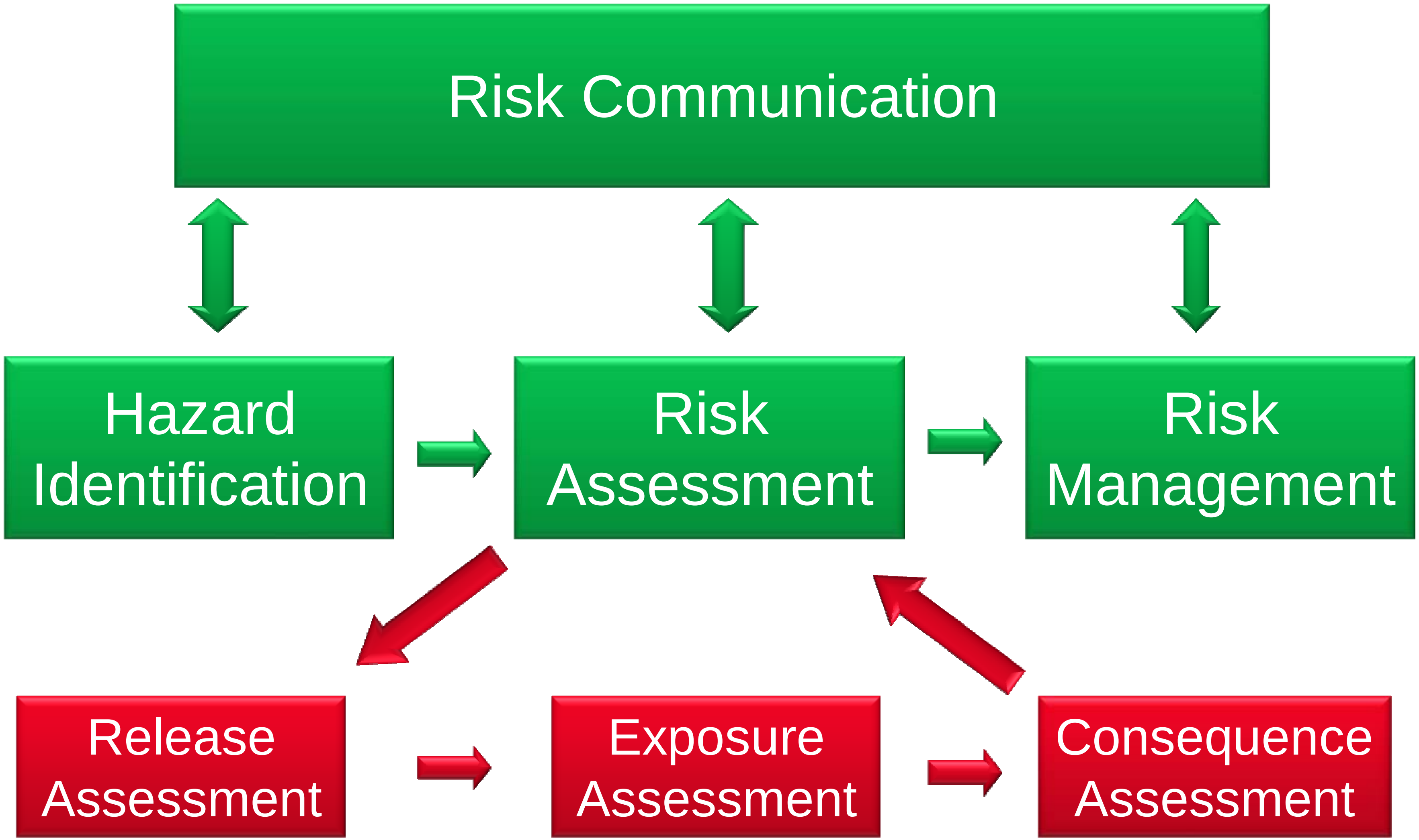
Asia's avian flu is spreading rapidly, increasing the risk that it will mutate into something far deadlier


With quakes and tsunamis, no one's got time for bird flu

The fight against the disease is unlikely to attract much attention from the resource-strapped Indonesian authorities until the flu becomes a mass killer

INDONESIAN VILLAGERS from the Karo district in North Sumatra, where seven family members died of the H5N1 virus, protesting against the local government's plan to cull chickens in the district.

Risk Analysis Components (after OIE Animal Health Code)



Possible Roles of Scientists in Policy Development

- value consensus AND low uncertainty
    - o no policy connection
        - **pure scientist**
    - o policy connection
        - **science arbiter**
- no value consensus OR high uncertainty
    - o need to reduce scope of choice
        - **issue advocate**
    - o no need to reduce scope of choice
        - **honest broker of policy alternatives**

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from Pielke 2007

Modelling in Policy Development Process

- risk assessment
  - quantify risks
  - identify key risk factors (explanation)
- risk management
  - guidance with respect to policy choices (prediction)

Modelling

- reflection of our understanding of ‘real world’
- explain or predict effects
- qualitative and quantitative
- focus on quantitative models
- needed where mental simulation not able to represent multiple causal links within system
  - limit usually reached with 3 variables and 6 transitions from one state to another (Klein 1998)

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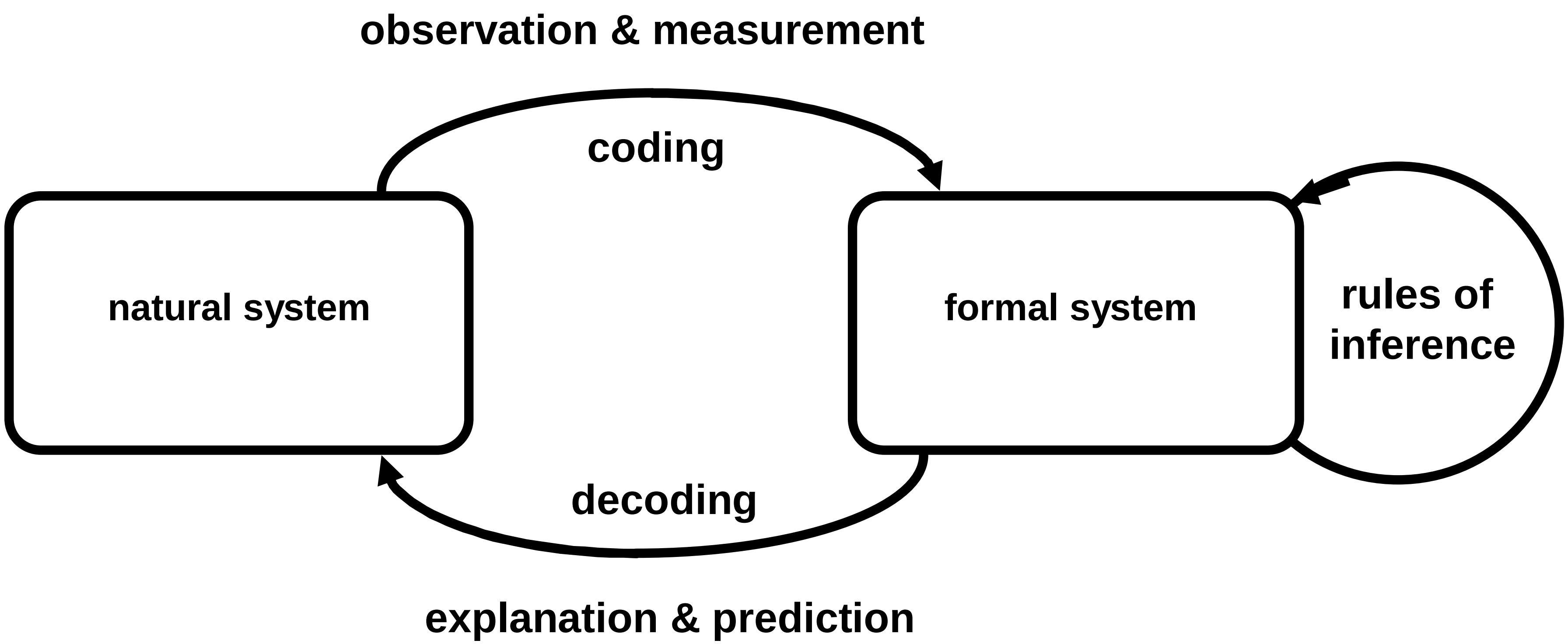
Models as Representation of Reality



(after Rosen 1984)

Quantitative Models

- used to generate information or knowledge from data
- "All models are wrong - but some are useful" (Box 1979)
- "… the establishment that a model accurately represents the 'actual processes occurring in a real system' is not even a theoretical possibility." (Oreskes et al 1994)
- *need to decide whether model good enough rather than true*
- data- and knowledge-driven models

Data-driven Modelling

- uses statistical approaches to derive quantitative relationships from datasets
- usually used for explanation
  - o to generate knowledge in relation to cause-effect relationships
- can be predictive

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Knowledge-driven Modelling

- based on existing understanding of biological relationships within system
  - or hypotheses in this respect
- strength and weakness -> ability to represent dynamics of complex biological systems
  - particularly important for infectious disease
    - propagation of infection inherently time-dependent
      - number of new infections at particular time depends on number of infectious and susceptible individuals at preceding points in time
- possible to identify key factors within system

Knowledge-driven Modelling *cont.*

- may have ‘emerging properties’ resulting from interactions between multiple effects represented in model
- can be used to test impact of changes in system
- includes knowledge derived from data-driven models as well as expert opinion

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Explanation and Prediction of Effects

- explanation
  - o to understand biological mechanisms that lead to occurrence of outcome
  - o particular strength of data-driven models
- prediction / forecasting
  - o knowledge about mechanism may also be of interest
  - o to understand what will happen in future
    - medium to long term
    - tactical usage during an outbreak
  - o with knowledge-driven models
    - possible to simulate different control scenarios

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Modelling Outcomes

- effect estimates
  - o risks
  - o economic impact
  - o comparative assessments
- uncertainty

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Uncertainty and Validity

- need to be considered when using outputs from modelling activities for informing policy development
  - o uncertainty (precision, random error)
  - o validity (bias, systematic error)
- influenced by assumptions, data quality and knowledge about biological system

Uncertainty

- uncertainty is the condition of all human life (after John Maynard Keynes)
- more than one outcome consistent with our expectations
  - o expectations influenced by knowledge and lack thereof, societal values and interests
    - science and technology needed to clarify expectations and facilitate desired outcomes

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Uncertainty *cont*.

- can increase with advancing knowledge due to complexity of systems

- *therefore ignorance is bliss because it is accompanied by lack of uncertainty*

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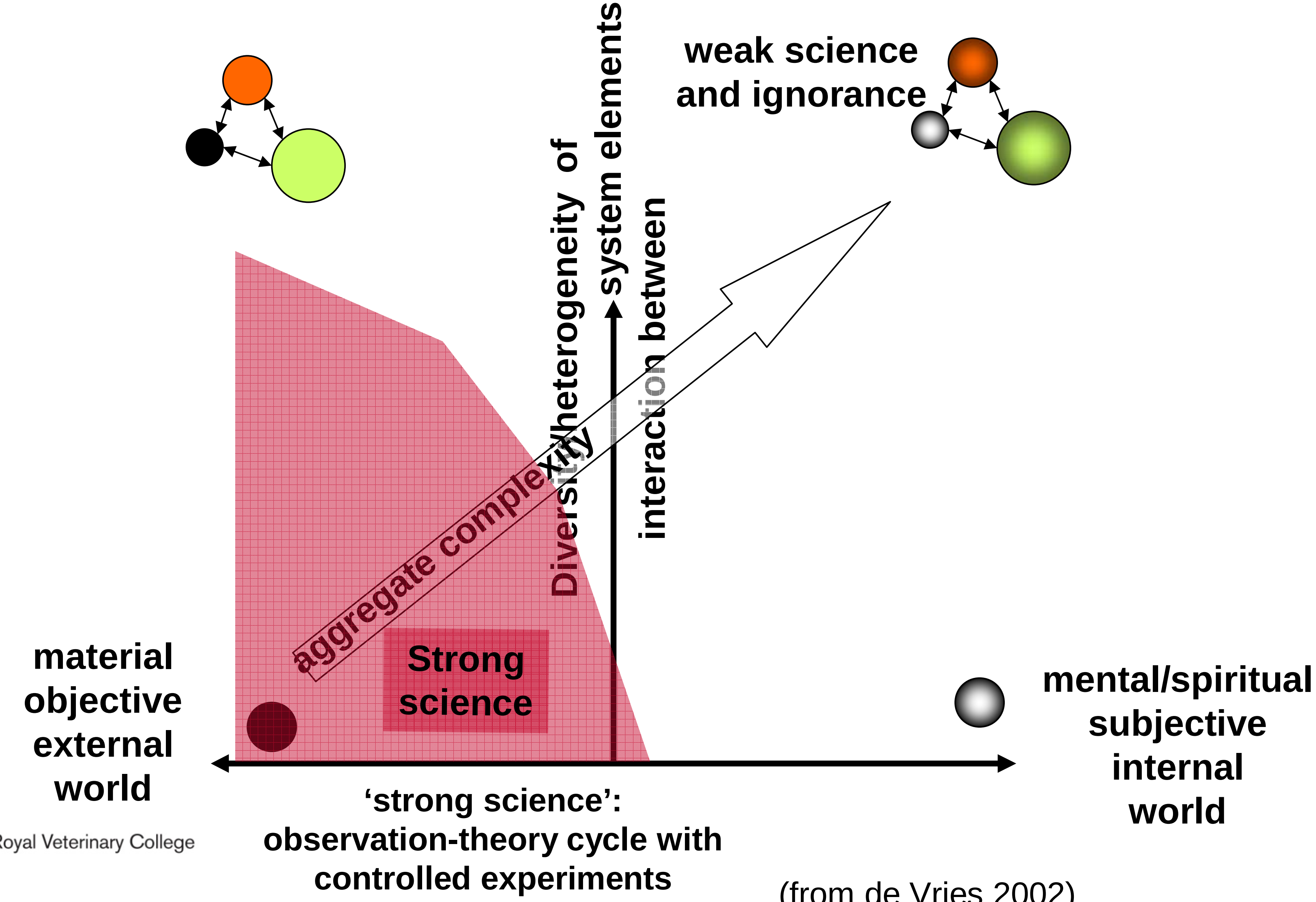
Validity of Data-driven Models

- internal validity -> factors resulting in incorrect inferences in relation to presence of relationships within dataset
- external validity -> ability to extrapolate

Validity of Knowledge-driven Models

- complex to assess validity of outputs
  - o typically based on quantitative relationships derived in very different studies, or from expert opinion
- usually assessed by comparing model behaviour with observed ‘real world’ system behaviour
- due to lack of suitable ‘real world’ data often necessary to consider plausibility of quantitative outcomes resulting from varying input parameters

Science, Models and Complexity



(from de Vries 2002)

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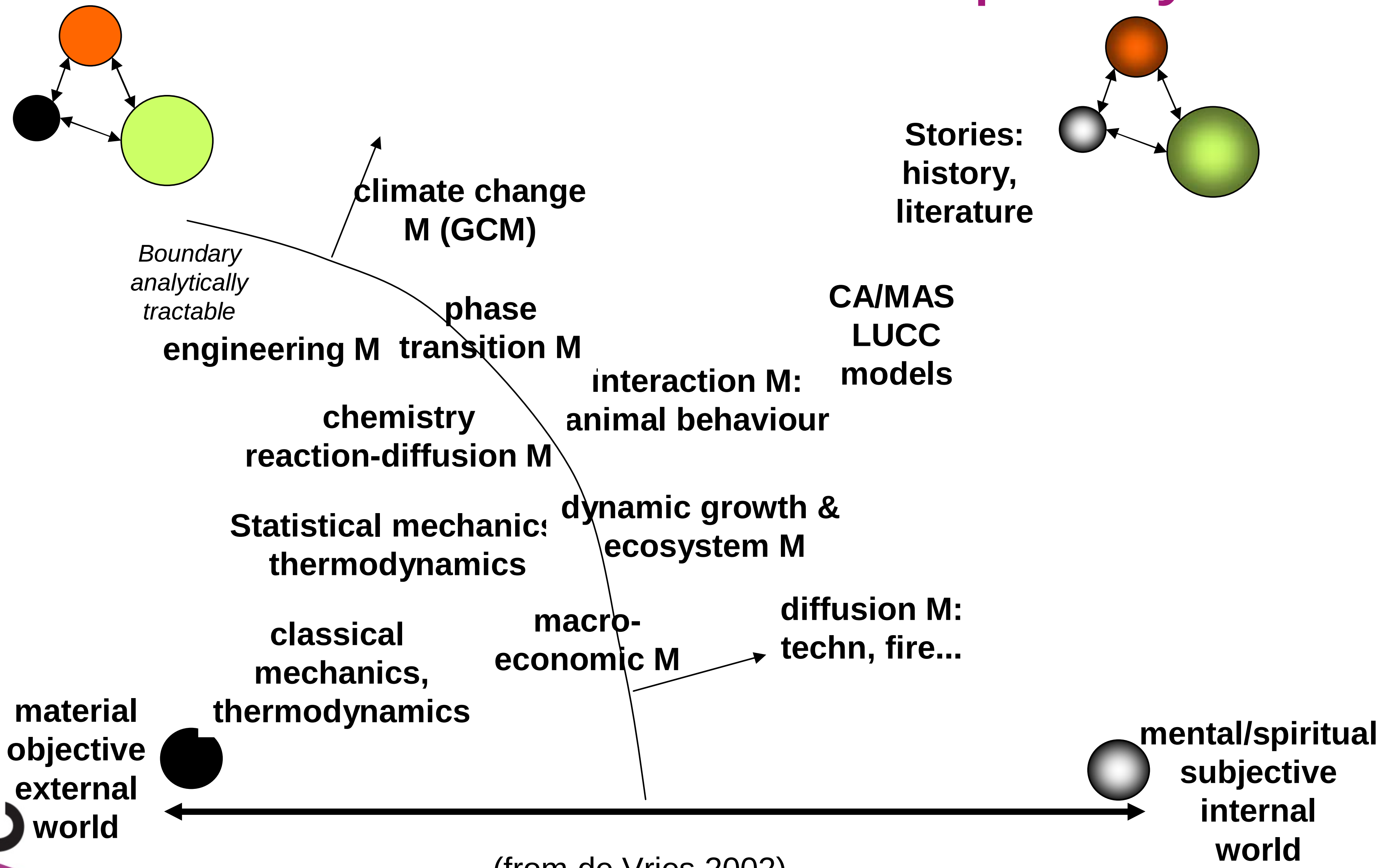
Models of Different Complexity



(from de Vries 2002)

Problems with Models of Natural Processes

- errors in characterisation of processes modelled
  - o use of averages
  - o scaling up
  - o substituting lab measurements for nature
  - o substituting mathematics for nature
  - o assuming linear relationships
- omissions of important processes
- lack of knowledge about initial conditions
- influences from outside modelled system

From Pilkey & Pilkey-Jarvis 2007

Examples (from UK)

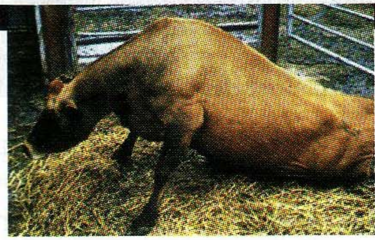
- BSE
- FMD
- Bovine TB

CHRONOLOGY OF A CRISIS

WHATEVER HAPPENED TO MAD COW DISEASE?

In 1996, BSE—or mad cow disease—spread food hysteria across the Continent, as 10 people died from a new form of Creutzfeldt-Jakob disease that was linked to contaminated beef. At one point, epidemiologists from Imperial College, London, predicted that vCJD could kill millions. So far, 139 have died, just a handful of them outside the U.K. The crisis is one of the most potent examples of how science can get risk wrong. A timeline:

1986 Bovine spongiform encephalopathy (BSE), an infection that riddles the brain full of holes, is identified in cattle at a farm in West Sussex, England.



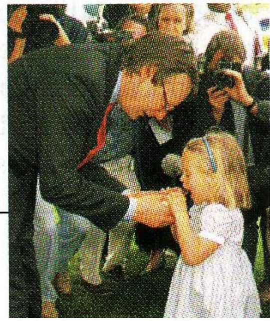
GREG WILLIAMS—REX FEATURES

1987 The British government announces that large numbers of cattle are infected with BSE. The probable cause: feed that contained meat or bone of sheep infected with scrapie.

1988 The government orders the slaughter of all BSE-infected cattle, above, and bans meat and bone meal in cattle feed.

1989 Britain bans human consumption of cattle brains, spinal cords and other body parts that some scientists suspect could affect human health.

1990 Donald Acheson, the Chief Medical Officer, assures the public that beef is safe to eat. To prove the point, Agriculture Minister John Gummer publicly shares a hamburger with his daughter, left.



ANGLIA PRESS AGENCY

1992 The infection peaks: three cows in every 1,000 have the disease.

1994 A new form of Creutzfeldt-Jakob disease (vCJD) is identified. The use of meat and bone in animal feed is banned in all E.U. countries, except Denmark. Six cases of vCJD.

1995 Stephen Churchill dies. He is the first confirmed vCJD fatality.

1996 Scientists conclude that vCJD is linked to exposure to BSE. The E.U. bans exports of British beef. Ten people die from vCJD. Mad cow mania is born.

1997 Scientists from London's Imperial College predict that up to 10 million people could die from vCJD. Ten more deaths from vCJD.

1998 Imperial College scientists predict that some 500,000 people will die in the epidemic. An enquiry into the BSE crisis hears from the father of Clare Tomkins, a vegetarian for 12 years and one of 18 to die from vCJD.

DAVID CHESKIN—PA

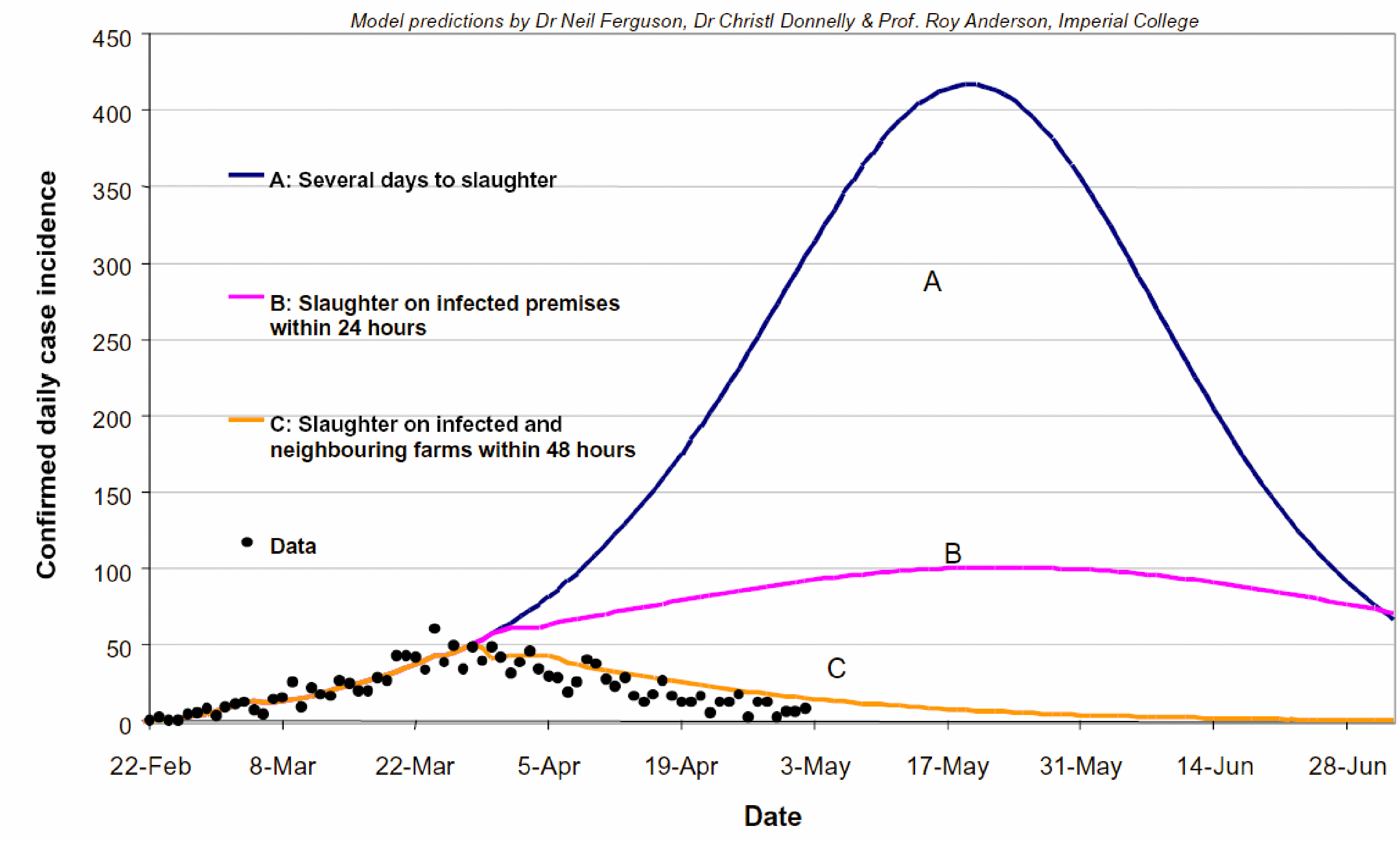
2000 Scientists predict up to 136,000 deaths from vCJD, while 28 people actually die from the disease. Since 1996, 4.5 million cattle have been slaughtered, left, at a cost of almost €3 billion.

2001 A team from the London School of Hygiene and Tropical Medicine says deaths from vCJD may number only a few thousand. Scientists investigating whether sheep could have BSE admit that for five years they had unwittingly tested cow brains, not sheep. Twenty more deaths from vCJD.

2002 Scientists predict that there will be 32 deaths from vCJD this year, and that fatalities will increase by 20% a year. Seventeen people die from the disease.

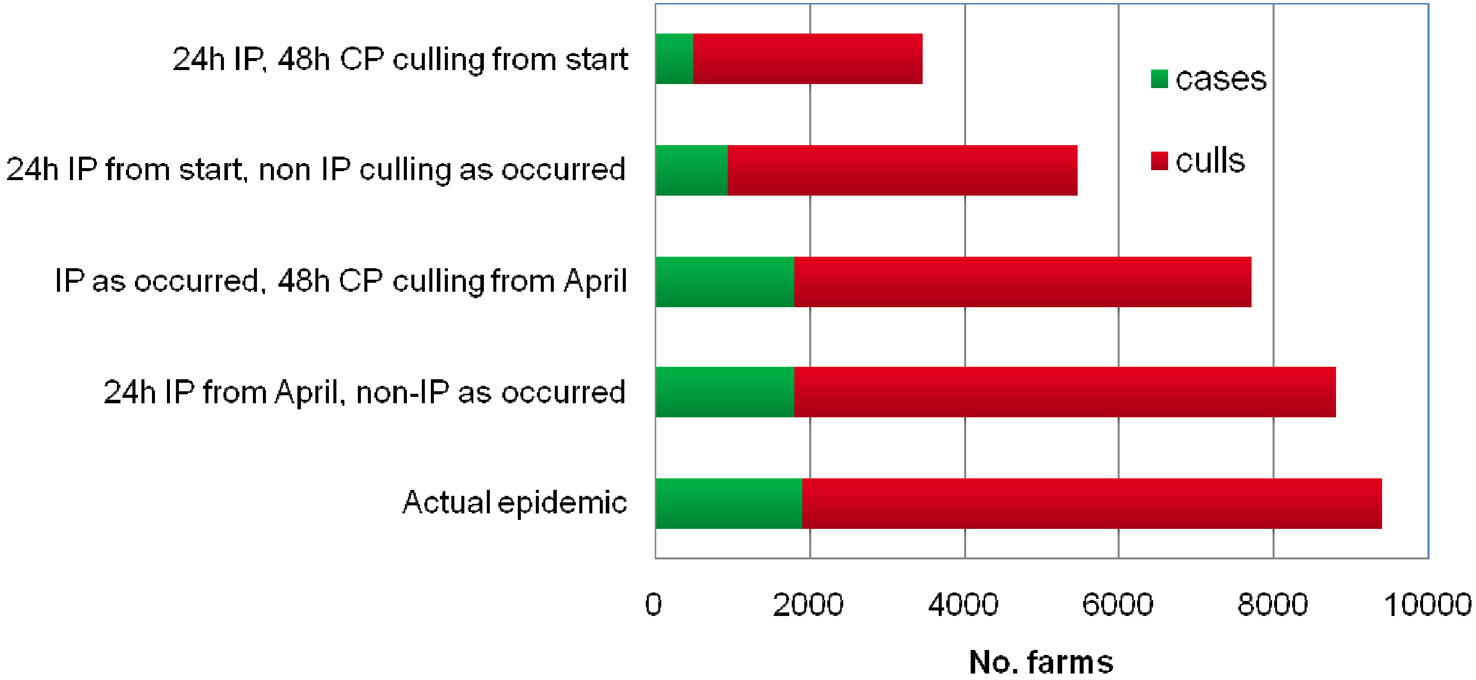
2003 In February, epidemiologists predict 7,000 will die from vCJD by 2080. By May, they say a maximum of 540, possibly as few as 40. Ten have died so far this year from vCJD, with four suspected cases. *—By Kate Noble*

UK FMD 2001



Model predictions by Dr Neil Ferguson, Dr Christl Donnelly & Prof. Roy Anderson, Imperial College
Confirmed daily case incidence
450
400
350
300
250
200
150
100
50
0
A: Several days to slaughter
B: Slaughter on infected premises within 24 hours
C: Slaughter on infected and neighbouring farms within 48 hours
Data
A
B
C
22-Feb
8-Mar
22-Mar
5-Apr
19-Apr
3-May
17-May
31-May
14-Jun
28-Jun
Date

UK FMD 2001: Consequential Reality and Theory of Models



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From: Anderson 2002 – FMD 2001: Lesson to be learned Enquiry Report

Bovine Tuberculosis: Species Diagram

Cattle (spillover and reservoir hosts)

Humans (spillover hosts)

Other Wildlife (spillover hosts)

Wildlife (reservoirs hosts)

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Bovine TB and Wild Badgers in UK

- risk of introduction of BTB to cattle herd
  - cause-effect relationships
    - between-herd transmission vs. wildlife reservoirs
  - 20 years political and scientific debate
    - in GB three government committee reports conclude
      - strong indications for significant role of badgers
    - badger population control methods considered inhumane

Bovine TB and Wild Badgers *cont*.

- UK badger culling trial to assess impact of badger TB on cattle TB, and effectiveness of badger population reduction (1998-2006 -> £40Mill)
  - o 10 clusters with three treatment groups of 100km^2 each
  - o preliminary finding in mid 2003
    - reactive treatment increases cattle TB reactor rate by 27% (95% CI -2.4%-65%; Donnelly *et al* 2003)
    - interpreted as 'likely' cause-effect relationship -> UK government stopped reactive trial activities
      - was decision justified given scientific evidence?
        - significant sources of sampling error and bias

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Conclusions

- predicting the future is not possible, but models can be a mechanism for making informed decisions
- modelling outcomes always associated with varying degrees of uncertainty and validity, which are often poorly communicated or understood

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Conclusions *cont.*

- scientists need to be conscious about their role in policy development process
  - o issue advocate *vs*. honest broker
- ultimately, decision to use models for informing policy making will have to be based on opinion and judgment

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