

The Great Acceleration

**Transdisciplinary Research on the Human Impact
on Global Earth Systems**

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**Response to the Grand Challenges in Global
Sustainability Research**

ICSU/ISSC/UNESCO

Paris, June 22, 2010

The International Council of Science Grand Challenges

On June 22, 2010 at UNESCO in Paris, the International Council for Science (ICSU) called for scientists to reform their own structure. Johan Rockström stated, “We have put ourselves in this position. There have been great advances in science. As scientists it is fundamental that we move towards institutional frameworks to support research for a more sustainable world.” He talked of “something profound and new” and of an “historic opportunity.”

Grand Challenges for Institutional Reform

The ICSU Grand Challenges for institutional reform have resulted from by thirty years of Earth systems research.

The Grand Challenges are informed by the scientists who participated in the August 2009, ICSU online visioning consultation – which had 1,016 registered users from 85 countries, and during which 323 research questions were posed.

The Grand challenges document draft has been reviewed by 46 institutions world wide and by 202 individuals scientists.

The final copy will be informed by participants at the ICSU Forum in Paris.

The Tremendous Message

The scientists at the ICSU forum were in agreement that global environmental change is outpacing the response, that our current path is unsustainable, and that immediate action needs to be taken to change the global impact of people on Earth System functions.

“The tremendous message,” one participant said, “is that we don’t know how far this will take us.”

The terms “scale,” “focus,” and “intensity” were used in this context for the work of restructuring research institutions – including universities and schools – to respond in this time of global emergency.

The Importance of Social Science and Humanities Participation

There was consensus that there is an urgent need to mobilize the social sciences – for there to be more deep social science and more global observation.

Large knowledge gaps within disciplines and between disciplines were discussed, and the need for transdisciplinary research was widely agreed upon.

Attention will be given not only to the supercomplexity of the interrelationships between atmospheric and ecosystem stressors and human activity, but *also* the supercomplexity of the interrelationships between the physical and social sciences.

The Call for Changes for a Sustainable World

There was agreement that we need to educate in a different way, and that we also need to improve the interface between science and policy communication.

There was also agreement that deep transformations in societies are needed.

The International Social Science Council Supports the ICSU Call for Reform

At the meetings in Paris, ISSC was represented by Heide Hackman who spoke of the partnership of ICSU and the ISSC, stating that “the integration of the social sciences and humanities is no longer a choice but a necessity” in framing the global challenges that confront Earth systems science.

She spoke of the urgent need to reach out to the broader social science community. Again the call was for transdisciplinary research.

American Education Research Association

“Inciting the Social Imagination”

The theme of the 2011 American Education Research Association’s convention is “Inciting the Social Imagination: Education Research for the Public Good.” The call for submissions states, “This focus encourages education researchers to draw on transdisciplinary theories and constructs, integrated methods, and research approaches that aim to answer a breadth of questions from causal to interpretive/descriptive.”

AERA – Moving Past the Policy Impasse

The AERA calls for research that “helps us avoid a kind of reductionism, quick fixes, and narrow conceptions of teaching/learning, assessment, curriculum, teacher preparation, and educational reform. ... to see through the political and polemical tangles can move us past the current policy impasse toward a new democratic vision of schooling.”

Transdisciplinary Research

There is the agreement between the positions of ICSU, ISSC, and AERA that more integrated research frameworks are required and that there is an urgent need for transdisciplinary research.

Transdisciplinary research merges disciplines and paradigms, creating spaces between disciplines in which new insights can be gained and new perspectives developed -- beyond the possible perspectives that could be gained from within an individual discipline.

Examples of Transdisciplinary Research

For those who know my early research, the concept of “family literacy” – which was coined in my doctoral research in the late 1970’s – is the result of transdisciplinary research in anthropology, sociology, psychology, linguistics and education. The research merged the disciplines in new, and at the time, provocative ways – once called “fuzz” by an eminent psychologist.

The research of the International Center for Everybody’s Child (ICEC) is also transdisciplinary, and focuses on the increasing exposure of children worldwide to catastrophic events, armed conflict, extreme poverty and public health emergencies – combining research from the social, biological and physical sciences.

Earth Systems Science and Social Science have become Inseparable

What is important here is that the Grand Challenges of Earth systems science and social science – including educational research - are converging.

Ecological justice and social justice have become inseparable, and each scientific organization is calling for transdisciplinary research.

Cataclysms and Kicks

At the ICSU Forum there was also general agreement that while dangerous changes are taking place over time, abrupt changes are most dangerous.

In physics abrupt changes that are unexpected and unpredictable are sometimes referred to as kicks.

In Paris cataclysm and cataclysmic were the descriptors used.

Cataclysm and cataclysmic are beginning to appear in articles published in science journals. Catastrophe has been increasingly used in research reports in recent years, but cataclysm ratchets up the potential for an unprecedented disaster.

The Great Acceleration

Ban Ki Moon, the Secretary General of the United Nations was quoted as saying in 2009 that “we have our foot on the accelerator driving towards the abyss.”

The term “accelerator” was taken up. There was talk of “the great acceleration,” and there was general agreement that the anthropogenic changes that are taking place are speeding up.

There was also talk of the “urgency” being “so daunting,” that there is a critical need for the scientific community to restructure to meet the challenges, and that under the present institutional structures scientists will not be able to answer in time the research questions that confront us.

The Need for a Public Vision of What's Happening

“Everything should be legitimized for the public,” one ICSU participant said. “They need a vision and a road map.”

I don't have a road map but I am going to try to make explicit – to demonstrate – why transdisciplinary research has become so critical for both Earth systems science and social sciences.

Essentially, it is an explanation of why the one can no longer exist without the other – why ecological and social justice have become inseparable.

Part Two

**How Can Social Scientists Participate in
Transdisciplinary
Earth Science Research?**

We Forget the Importance of Language at Our Peril

“Words,” Iris Murdoch writes, “are the most subtle symbols which we possess and our human fabric depends on them. The living and radical nature of language is something which we forget at our peril.”

Murdoch writes, “We learn through attending to contexts,” and “we can only understand others if we can to some extent share their contexts.” She then states, “Often we cannot.”

The Study of Language as a Social Practice Provides a Portal for Analysis

Any global sustainability efforts will be highly dependent on the ability of all those who participate to take into consideration the inter/multi/trans-disciplinary and inter/multi/trans-professional challenges of working with participants who hold different views of science and, quite possibly, humanity.

Language analysis provides a portal to explore research across disciplines on the complex dynamic relationships between the social and physical sciences.

It is imperative that basic research continues, but within broader frameworks that take into consideration transdisciplinary perspectives.

Language Analysis Creates Opportunities for Social Scientists to Participate in Earth Systems Research

Language analysis creates opportunities for scientists to deconstruct research across a wide range of disciplines and disciplines – to analyze, document, and respond to:

Meta-worries about metatheories;

Problems that arise from working in complementary and contradictory paradigms;

Concerns about reductionism and expansionism;

Questions about the super-complexity of research studies;

Worries about systemic risk.

The Language Challenge for Earth Systems Scientists

By focusing on language:

The positionality of researchers can be taken into consideration;

Issues about participation and collaboration in sustainability research across disciplines and professions can be clearly articulated;

Questions of communication across disparate discourse communities can be incorporated into the design of research on global sustainability efforts.

But How Do Scientists Communicate Information?

The task facing Earth systems scientists is fraught with difficulties – not only of science but also of communication about science.

Scientists can do the research that they are eminently qualified to carry out – but how do they communicate the information to the public?

It is also of critical importance that attention is given to the communicative practices in, amongst, and between, the various discourse communities – scientists, policy makers, media - to which people belong.

It should not be left to the public to figure it out.

Complexities of Communication Within Human Societies

The difficulties that Earth scientists face are compounded by the complexities of communication within human societies.

All knowledge is contested – even when life begins and when life ends - and is highly dependent on the social, cultural, national, religious, and political groups to which people belong.

Human activity is highly dependent on the discourse communities to which people belong, and that are constitutive of their everyday lives.

Bending the Curves

At the ICSU Forum scientists spoke of “bending the curves” and of “risks too high to take.” Mentioned specifically were: CO₂ (carbon dioxide), N₂O (nitrous oxide), and CH₄ (methane) concentrations; land degradation; and biodiversity loss.

Concern was expressed about changes in the global ecosystem functioning, and terrestrial and marine carbon. Similarly, concern was expressed about “the robust warming of the global upper ocean.”

What are people expected to make of all this? It’s not easy for the public to figure it out – especially when the media is filled with misinformation and disinformation.

Atmospheric Carbon Dioxide Increasing Rapidly

“The growth rate of atmospheric carbon dioxide (CO₂), the largest human contributor to human-induced climate change, is increasing rapidly.”

Three Processes Contribute to the Rapid Increase

“Since 2000, a growing global economy, an increase in the carbon emissions required to produce each unit of economic activity, and a decreasing efficiency of carbon sinks on land and in the oceans have combined to produce the most rapid 7-year increase in atmospheric CO₂ since the beginning of continuous atmospheric monitoring in 1959. This is also the most rapid increase since the beginning of the industrial revolution” (p.18868).

Josep G. Canadell et. Al. PNAS, November 20, 2007.

www.pnas.org/cgi/doi/10.1073/pnas.0702737104

Global Atmospheric CO₂ Concentration is Highest in 650,000 Years

“Global atmospheric CO₂ rose from 280 ppm at the start of the industrial revolution (approximately 1750) to 381 PPM IN 2006. The present concentration is the highest during the last 650,000 years and probably during the last 20 million years. The growth rate of global average atmospheric CO₂ for 2000-2006 was 1.93 ppm per year....This rate is the highest since the beginning of continuous monitoring in 1959 and is a significant increase over growth rates in earlier decades” (p. 18866).

Josep G. Canadell et. Al. PNAS, November 20, 2007.

www.pnas.org/cgi/doi/10.1073/pnas.0702737104

How Can Scientists Communicate this Information?

The rules have changed, communication has gone viral – calculated, haphazard – with unforeseen consequences (Baudillard)

There is an implicit assumption that if scientists publish their research, the media will publish their findings, people will read it and policy makers will act .

For this to happen every one would have to agree and our proclivity is to disagree – again all knowledge is contentious— but it’s even more complicated than that— the findings of research are filled with uncertainty, often ambiguous, and vulnerable to “kicks.” Models are a case in point.

The Models Caveat

- Models are not real systems;
- Models are useful for understanding small systems but not for huge systems – lots of things can change quickly;
- Models are useful fictions – complex systems without the kick—that are highly dependent on scale and complexity;
- Models are vulnerable to too many kicks – lots of things can change very quickly (the “who knew” phenomenon);
- Models can provide useful information – including warnings -- but not answers;
- Models can be wrong in many ways, but right in some ways that are useful;
- Models combined with other models provide compelling evidence.

Part Three

Re-Visioning for the Public the SuperComplexity of Earth Systems and Human Activity

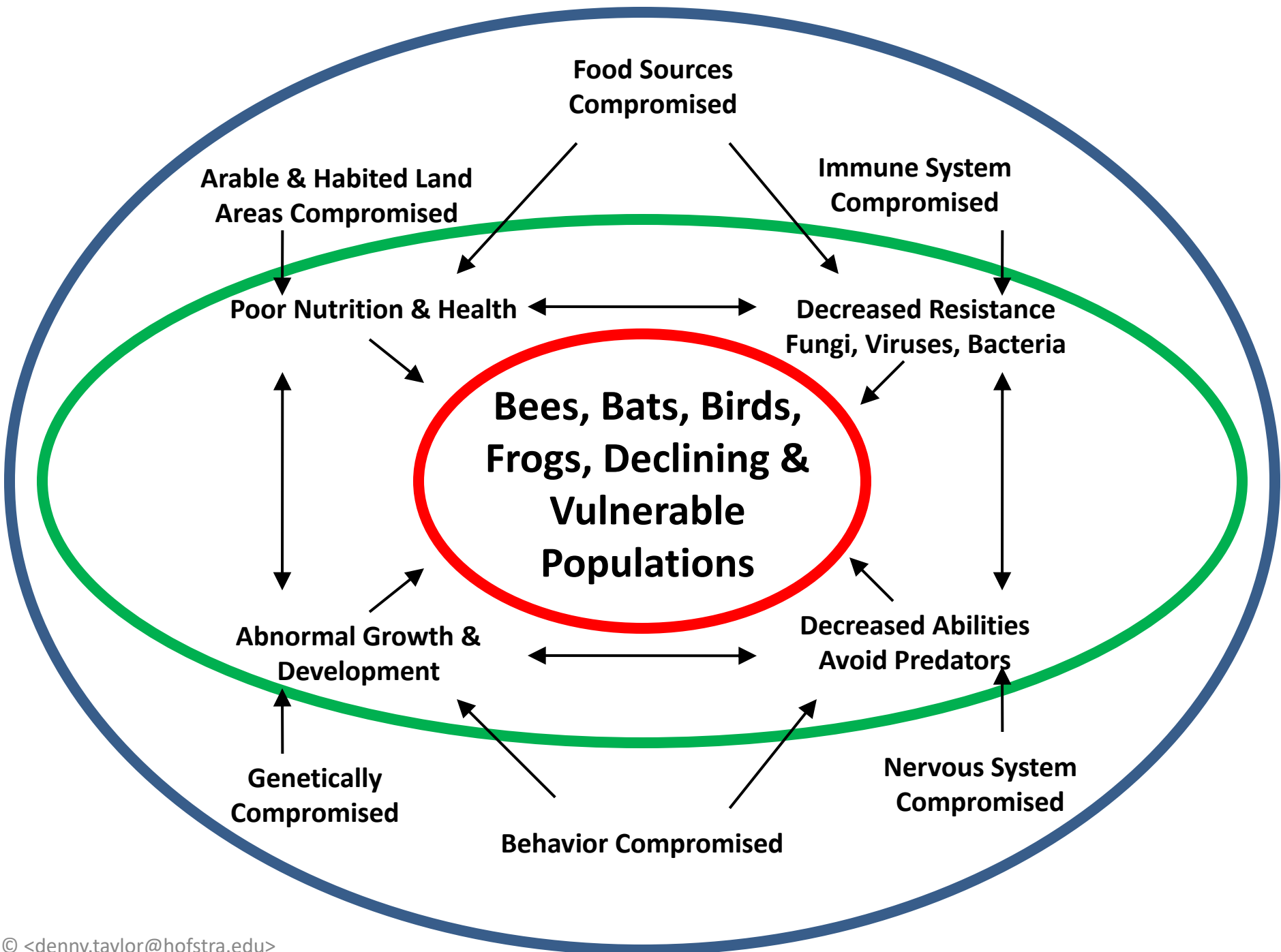
A Transdisciplinary Representation

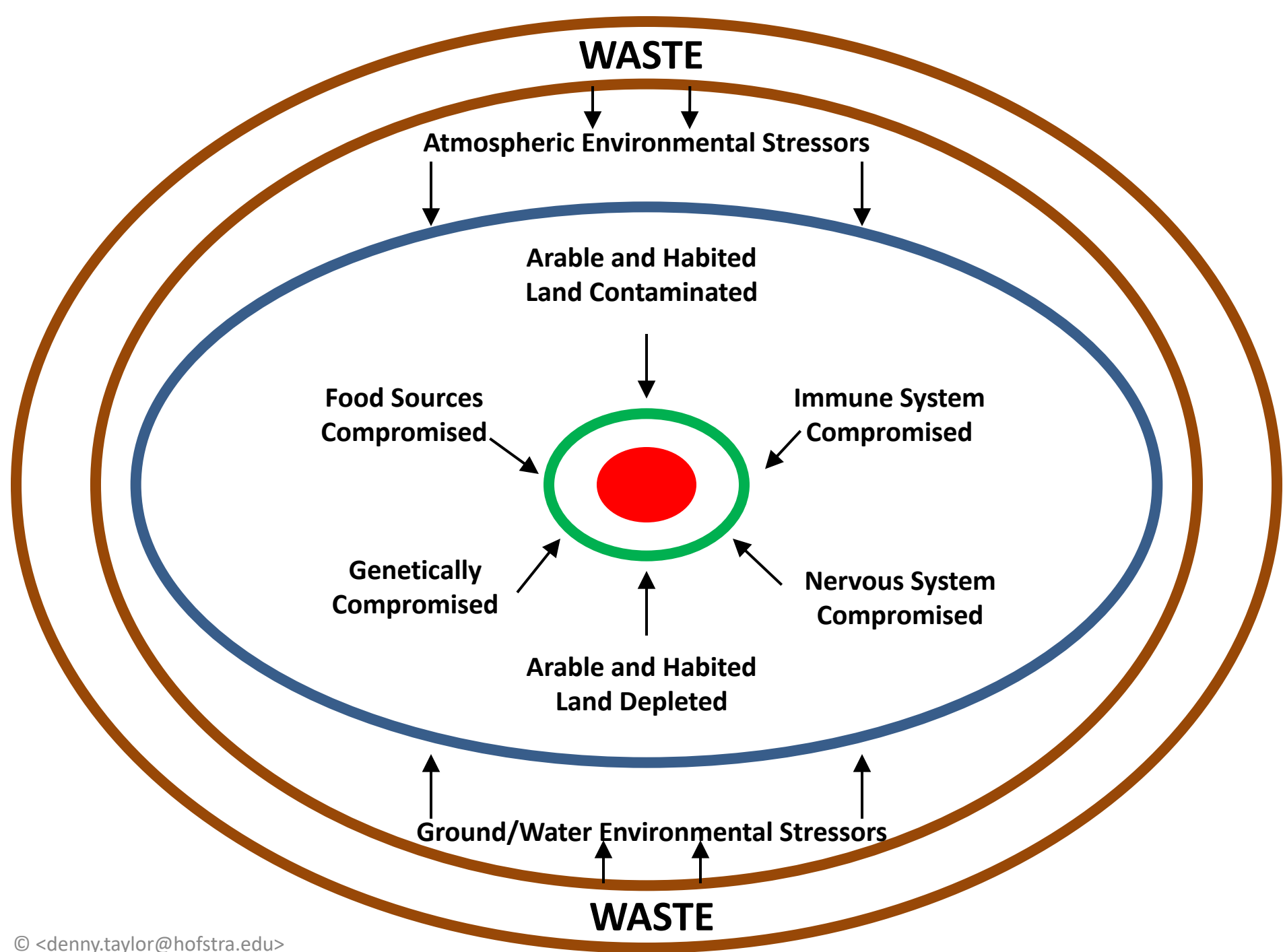
Navigating the Anthropocene

Some observers recognize today the dawn of an entirely new era in planetary history, the “anthropocene” The impacts of human activities are so pervasive and profound that they could inadvertently alter the Earth System in ways that may prove irreversible and inhospitable to humans.

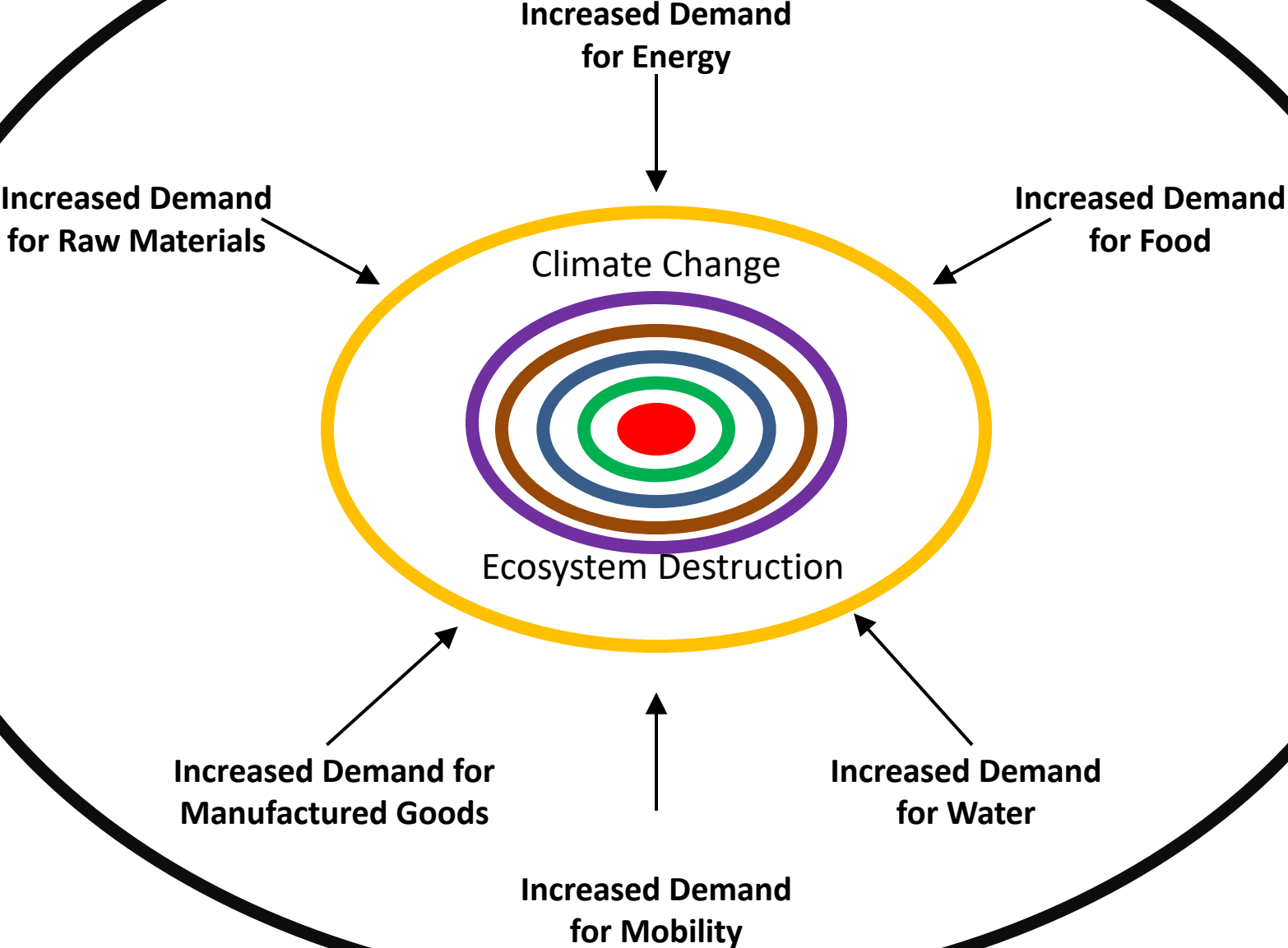
It is apparent that the institutions, organizations and mechanisms by which humans currently govern their relationships with natural environment and global biochemical systems are not only insufficient – they are also inadequately understood.

Biermann, F., et. al. (2010) Navigating the Anthropocene. *Environmental Sustainability*, 2010, (2) 1-7. www.sciencedirect.com)

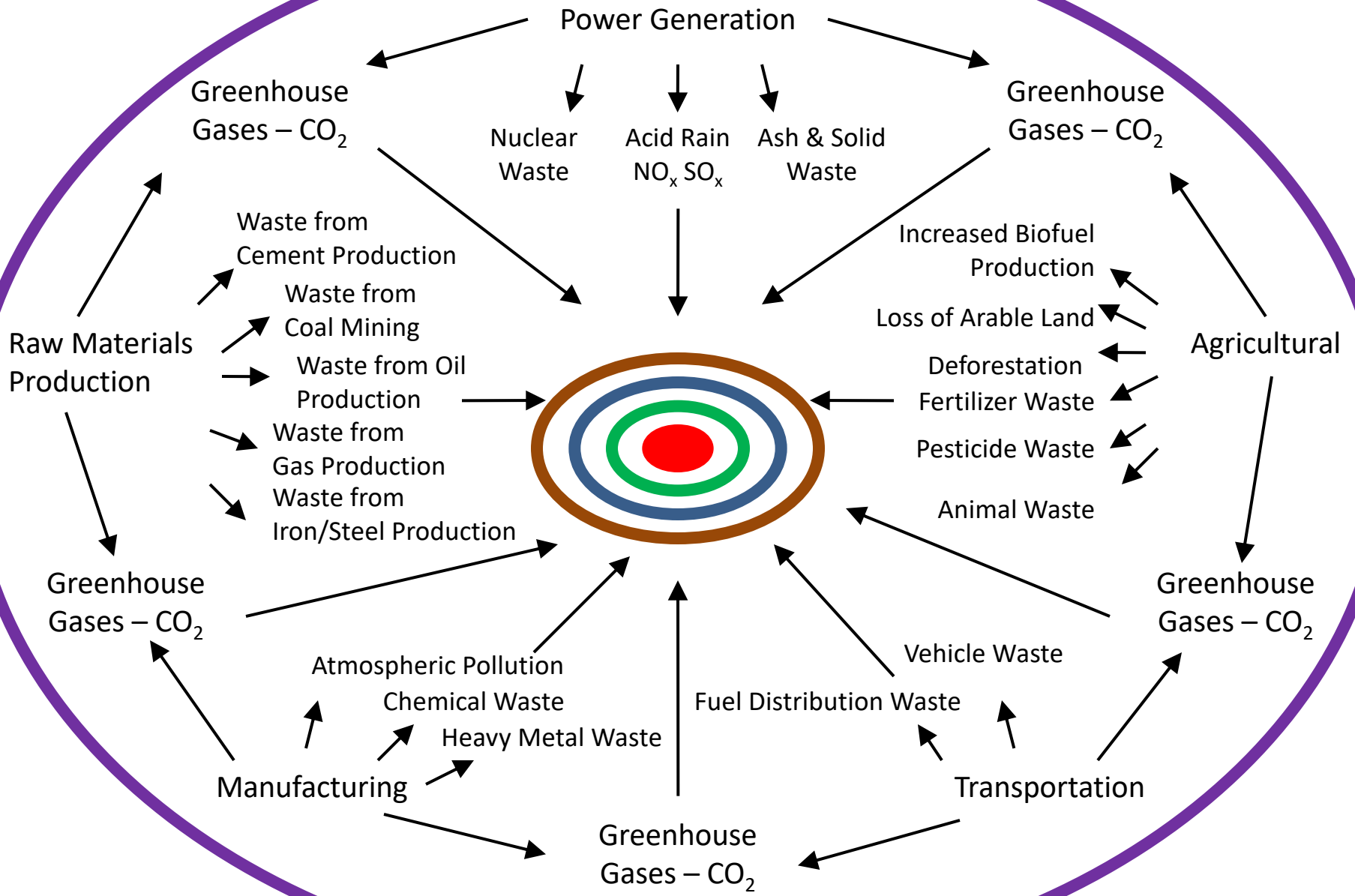




Human Activity

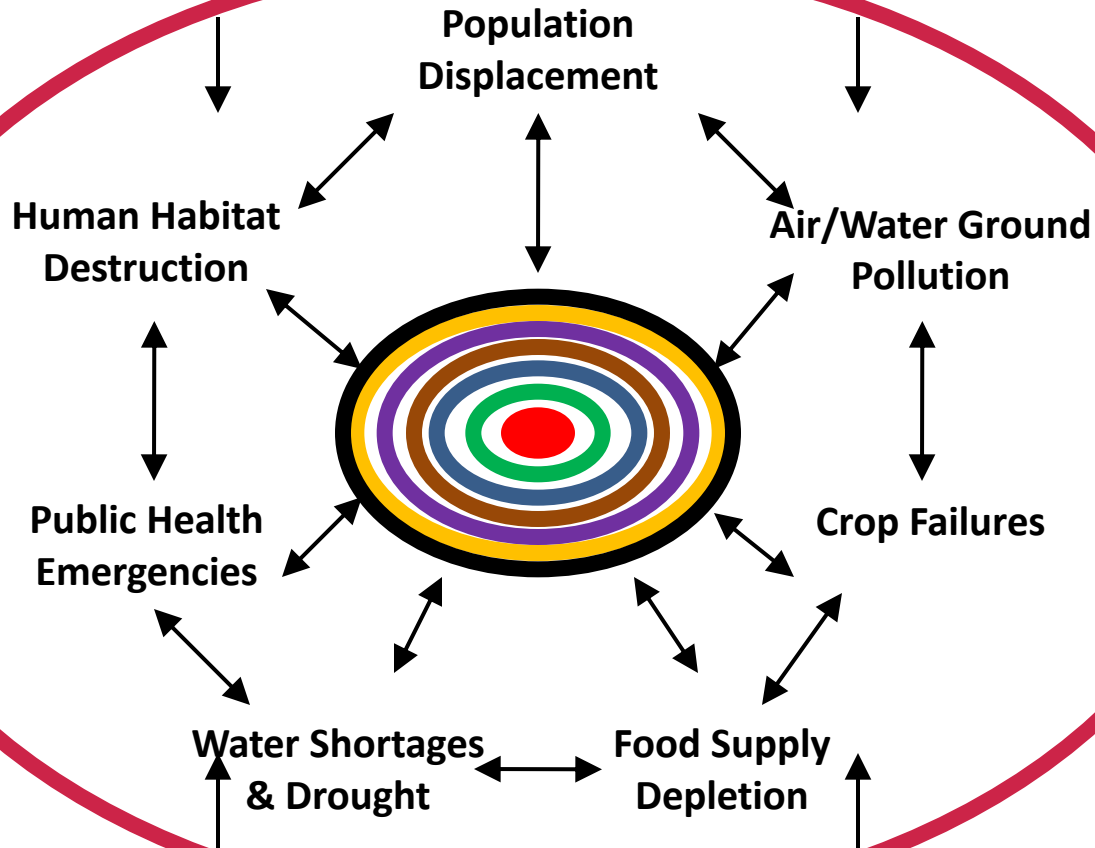


Climate Change

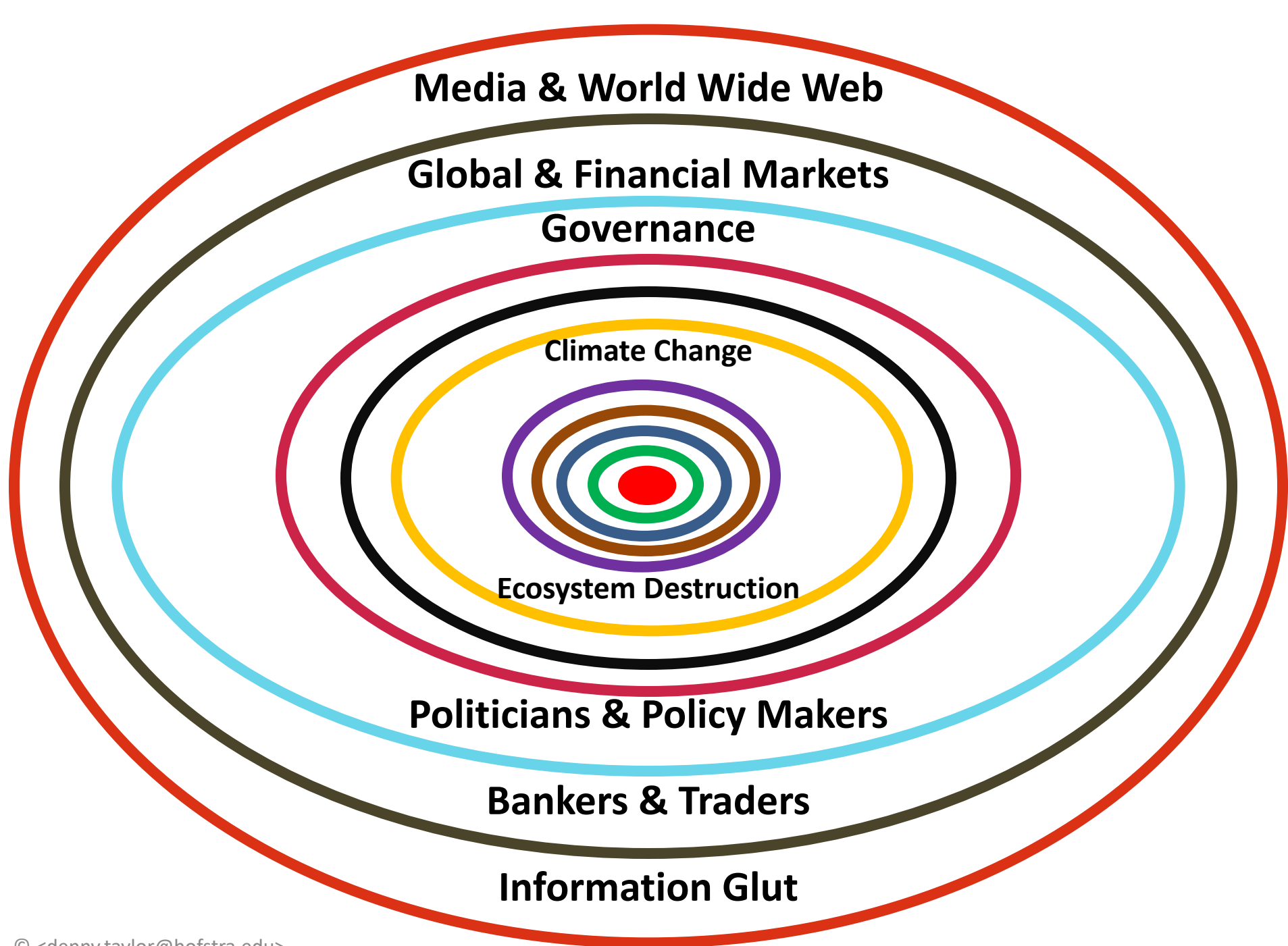


Ecosystem Destruction

Natural Disasters – Earthquakes, Tsunamis, Hurricanes



Global & Regional Armed Conflicts



Global and Financial Markets

Jean Baudrillard in his *Essays on Extreme Phenomena* writes of “an economy freed from ‘Economics’ and given over to pure speculation; a virtual economy emancipated from real economics (not emancipated *in reality*,) of course, we are talking about *virtuality* – but that is the point too: today, power lies not in the real but in the virtual; and an economy that is viral, and which connects with all other viral processes” (p. 34)

Virtual Money

Again Baudrillard. He uses the word “shattering” when he writes of the “mass of floating money whirling about the Earth in an orbital rondo. Money is now the only genuine artificial satellite. A pure artifact, it enjoys a truly astral mobility; and it is instantaneously convertible. He writes of the economics of “special effects,” of “unseeable events,” and an irrational interplay of forces” (pp. 33-34)

Media and the World Wide Web

Baudrillard, once more. He writes, “The striking thing about all present-day systems is their bloatedness: the means we have devised for handling data – communication, record keeping, storage, production and destruction – are all in a condition of ‘demonic pregnancy’ (to borrow Susan Sontag’s description of cancer). ... So many reports, archives, documents – not a single idea generated ... So many messages and signals are produced and disseminated that they can never possibly all be read(p. 32).

Earth Systems and The World Wide Web

The great acceleration of climate change and the destruction of the Earth's ecosystems is in part due to the great acceleration of virtual communications. If we take another look at the graphic on human activity – the increase in power generation, raw material production, manufacturing, transportation, and agriculture are all directly affected by the speed of communication.

The Communications—Human Activity Paradox

Paradoxically, while the acceleration of communications increases the rate of human activity, it also slows the rate at which we are reacting to the Earth systems changes.

Baudrillard's bloat is the global surfeit of information – foreign affairs, public relations, contradictory, haphazard, calculated to destabilize, filled with deception, irrational, national, religious, virtuous, filled with concern for the common good, corrupted by self interest.

The Paradox of Inertia and Endless Stimulation

“We know we don’t have the votes,” Harry Reid is quoted as saying about the Climate Bill, in an article buried in the lower right hand corner of page 12 of the National Section of the *New York Times*, Friday, July 23, 2010. And so the bill to reduce carbon emissions was dropped.

In *Laugh Lines*, *NYT*’s Week in Review, there’s a Tony Auth cartoon from the *Philadelphia Inquirer* – the Capitol Building under water except for the dome, and in a speech bubble is written “We regret that we have but one country to give for our lifestyle.”

The reality of climate change cannot compare with the virtual world of endless stimulation - Facebook, My Space, and Twitter keep us occupied.

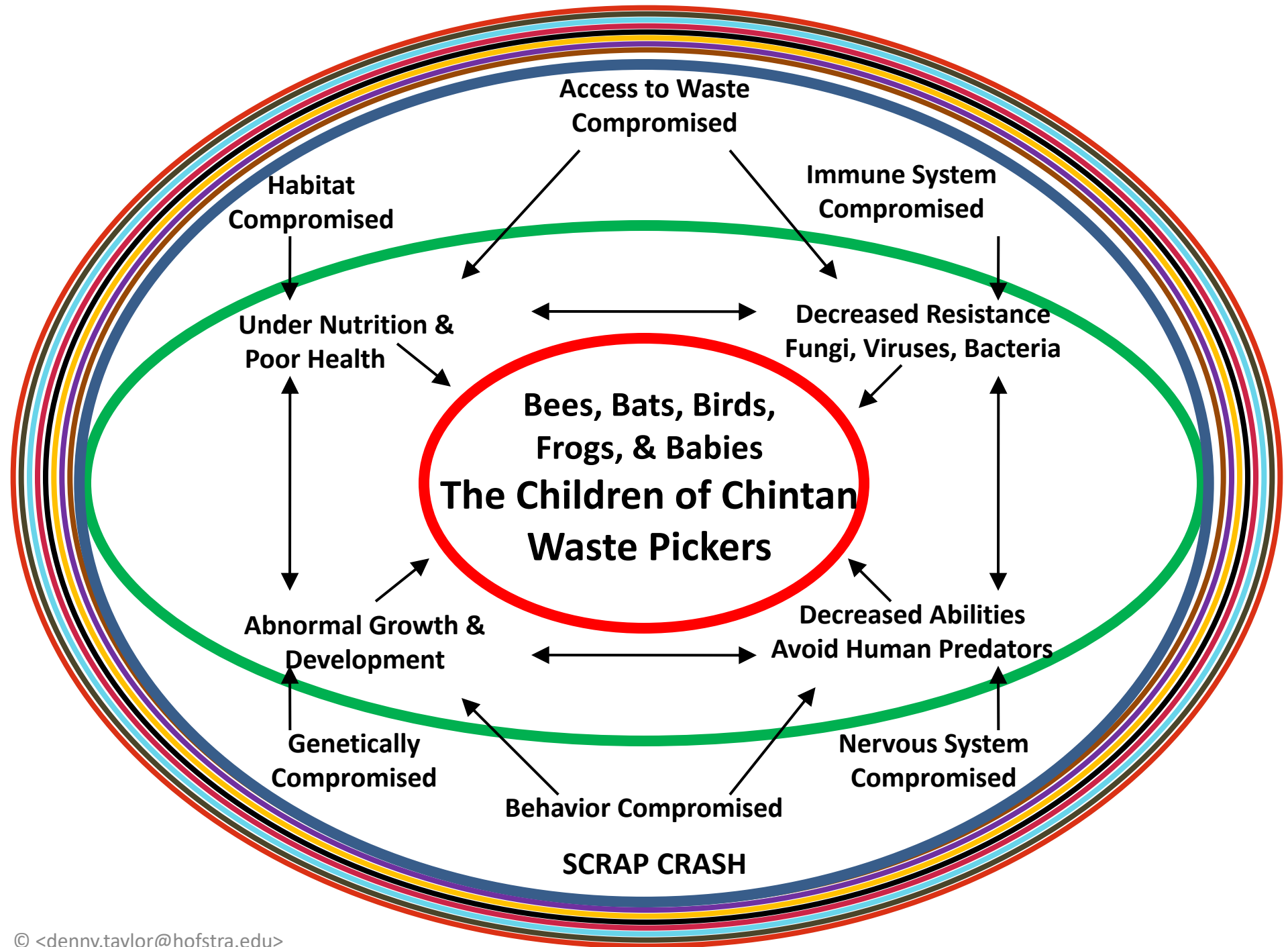
Virtual Communities are Transcending the Limits of Real World States

- China: 1.35 billion people
- India: 1.21 billion people
- Facebook: 500 million people
- United States: 310 million people
- MySpace: 300 million people
- Indonesia: 232 million people
- Brazil: 195 million people
- Twitter: 124 million people

Sources: UN; US Census Bureau; Facebook; MySpace; Twitter

Nobody is Asking How are the Children?

“Not well,” we would have to answer. “Their future is uncertain. We do not know what will happen to them.”



Ecological Justice and Social Justice are Constitutive of Each Other – You Cannot have One Without the Other

Human interference with planetary systems is increasing rapidly ...

New Perspectives and research are needed to understand the complex relation between global transformations of social and natural systems ...

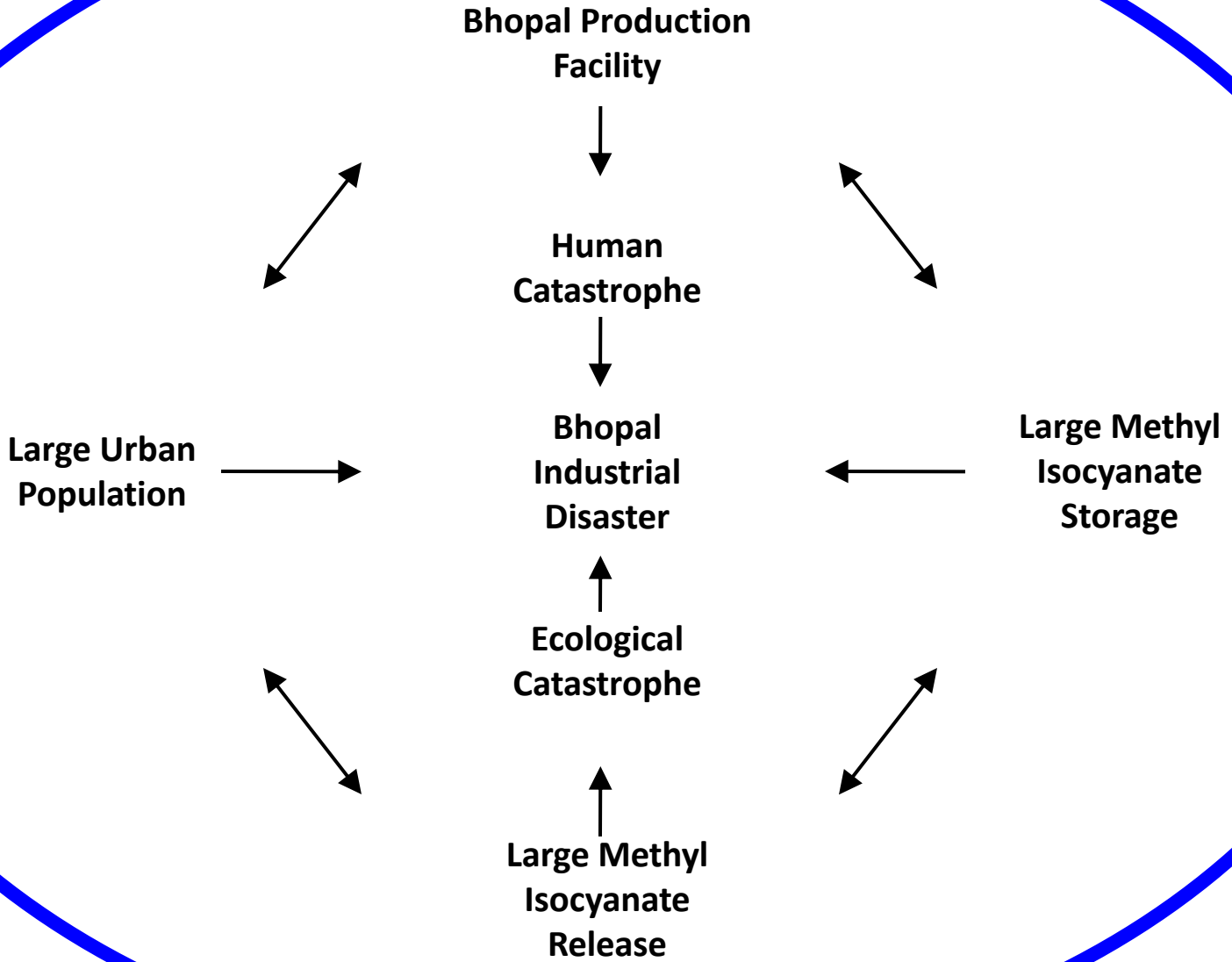
Innovative research is needed also to analyze political options to govern sustainable development – taking into account not only political effectiveness and efficiency but also global and national justice and equity

Biermann, F., et. al. (2010) Navigating the Anthropocene. *Environmental Sustainability*, 2010, (2) 1-7. www.sciencedirect.com)

Union Carbide Made Pesticides at the Bhopal Chemical Plant

The Bhopal was similar to the plant that was built by Union Carbide in Institute, West Virginia.

After the accident at Bhopal, Union Carbide shut the West Virginia plant and before they reopened it they retro fitted bigger safety valves – so it was more by luck than judgment that a similar accident did not occur in the United States.



Methyl Isocyanate (MIC)

Methyl isocyanate is the final intermediate chemical in the production of the insecticide/pesticide carbaryl, which is marketed/sold under the trade name Sevin.

In a New Times Article (January, 30, 1985) Stuart Diamond writes:

The Union Carbide Corporation technical manual for methyl isocyanate is pointed on the hazards of the chemical and states that it “may cause fatal pulmonary edema,” which is an accumulation of fluid in the lungs. But although the manual was distributed ... at the Bhopal plant ... most factory workers had not read or understood it, according to a former technical officials at the factory.”

Bhopal A Human Catastrophe and Environmental Disaster

By 7:00AM 70 people were dead, by 9:00AM 260 people were dead and thereafter the figure continued to rise. Though not all dead bodies were brought to the Medico-Legal Institute (MLI), 311 bodies were received on 3.12.1984, followed by another 250 on 4.12.1984. ... 103 in 1985, 90 in 1986 and 44 and 22 respectively in 1987 and 1988. ... (Sriramachari, 2004)

Sriramachari, S. (2004) Histopathology and toxicology: S. *Current Science*, vol 86 (7) 10 April.

Clinical Symptoms Observed During Acute and Sub-acute Phase (1-6 months) Following Methyl Isocyanate Exposure

Ocular: Intense irritation, burning, photophobia, blurred vision, corneal ulcer, conjunctival and circumcorneal congestion

Respiratory: Breathlessness, chest pain, severe dry or wet cough, pulmonary edema, distress, pneumonitis

Psychological & neurological: Anxiety, neurotic depression, social adjustment problem, impaired auditory and visual memory, attention response speed and vigilance

Reproductive: Spontaneous miscarriages, perinatal and neonatal mortalities, menstrual irregularities

Immunological: Suppressed cell mediated immunity, reduced T cell count, downregulation of phagocytic activity of lymphocytes

Gastrointestinal: Persistent diarrhea, anorexia, abdominal pain

Genetic: Increased chromosomal abnormalities

General: Muscle weakness, sleepiness, loss of appetite, nausea, vomiting, fever

P.K. Mishra, P.K., et al., (2009) | Bhopal Gas Tragedy: Review of Clinical and Experimental Findings after 25 Years. *International Journal of Occupational Medicine and Environmental Health* 2009; 22(3): 193-202

Clinical Symptoms Observed during Chronic Phase (6 months onwards) Following Methyl Isocyanate Exposure

Ocular: Damage to posterior ocular chamber, corneal opacity, conjunctivitis, chronic lesions, and deficiency of tear secretion

Respiratory: Cough (with or without expectoration), chest pain, dyspnea, wheezing, decreased lung functions, obstructive and restrictive airway diseases, acute extrinsic allergic bronchio-alveolitis

Psychological & neurological: Defective standard progressive matrices, associated learning, motor speed precision test, muscle aches

Reproductive: Increased pregnancy loss, infant mortality, decreased placental/fetal weight

Immunological: Hyper-responsiveness of immune system in *in-utero* exposed individuals

Cancer: Marginal increase in oropharynx cancer

Adolescent growth pattern: Growth retardation in exposed adolescent males

P.K. Mishra, P.K., et al., (2009) | Bhopal Gas Tragedy: Review of Clinical and Experimental Findings after 25 Years. *International Journal of Occupational Medicine and Environmental Health* 2009; 22(3): 193-202

**Lack of Methyl
Isocyanate Release
Monitoring**

**8,000 people
killed**

**200,000 people
debilitated**

**Lack of Urban
Development
Planning**

**Large Urban
Population
Devastated**

**Lack of Atmospheric
Dispersion
Modeling**

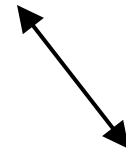
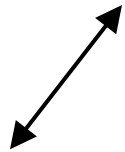
**500,000 people
registered
victims**

**4,000 livestock
killed within
minutes of
exposure; 15,000
died within months**

**Lack of
Emergency
Planning**

Union Carbide

Inadequate Plant
Safety Analysis



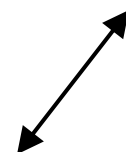
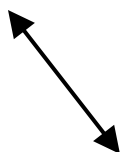
Inadequate
Personnel Training



Large Quantity of
Methyl Isocyanate
Released



Inadequate Plant
Safety Systems



Inadequate Operating &
Emergency Procedures

Union Carbide

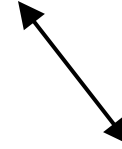
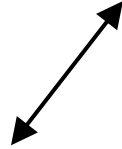
In Bhopal Key Safety Systems Were Disabled

The key safety systems were: (1) refrigeration that slow down the chain reaction; (2) vent gas scrubber designed to remove methyl isocyanate from any released gases; and (3) the flare system which is the last line of defense – basically a burner with the top of the pipe 33 meters +/- 100 feet above the ground.

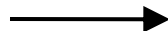
So there were three preventative systems – refrigeration, scrubber and flare. All were non-functioning.

Union Carbide

Selection of
Production Process



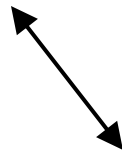
Plant Operation
Practices



Large Quantity of
Methyl Isocyanate
in Storage Tank

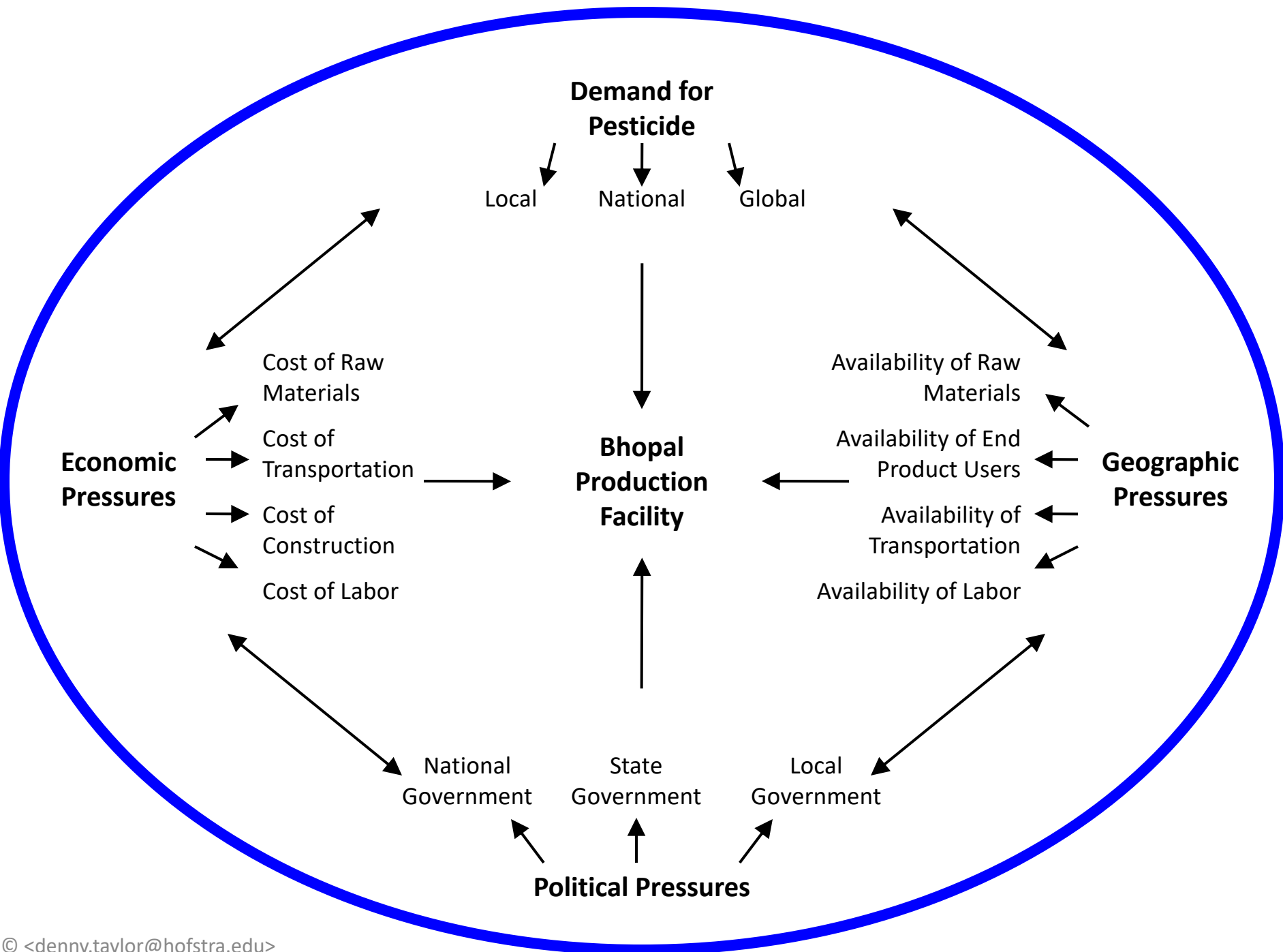


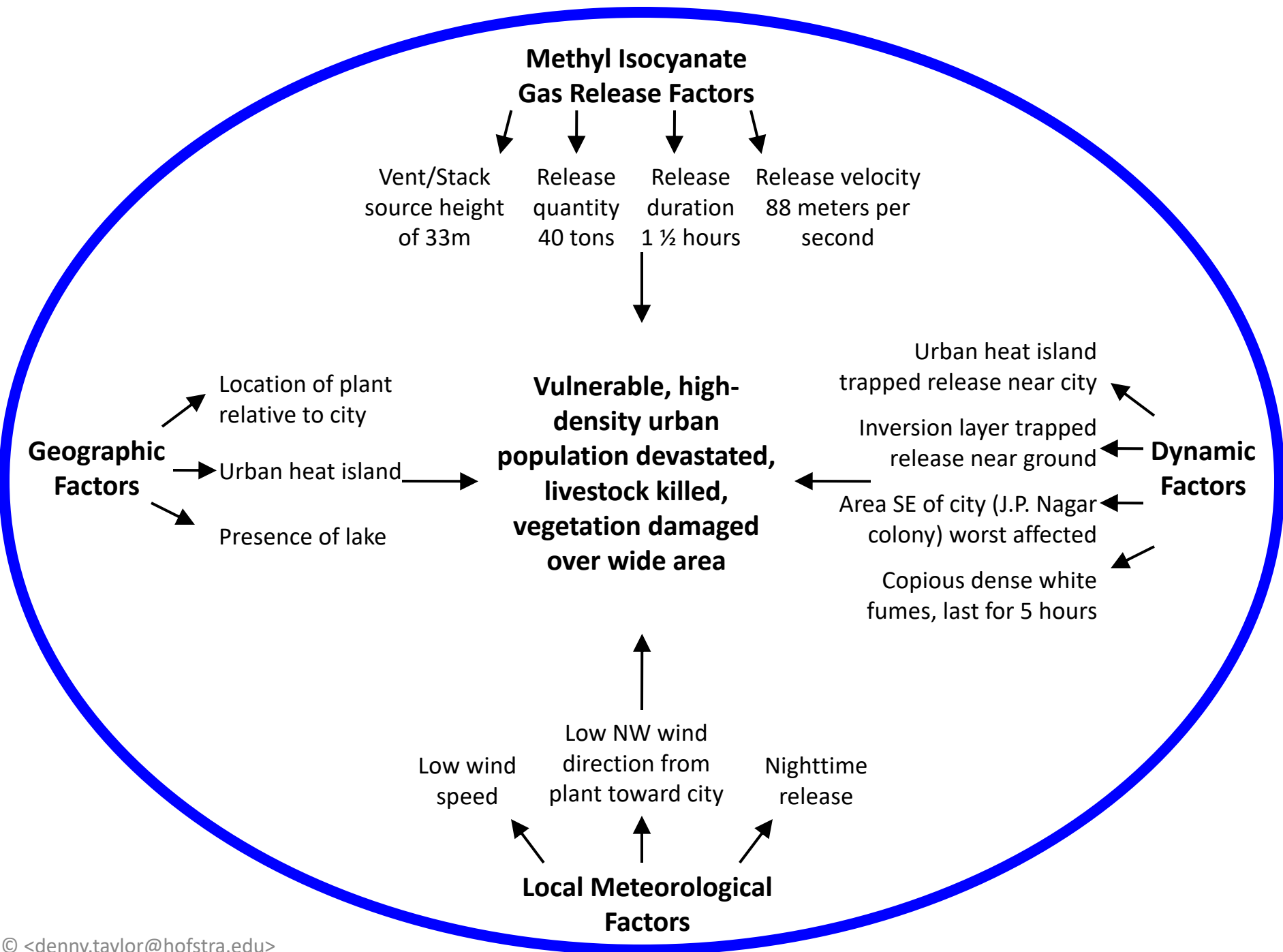
Selection of
Plant Production
Capacity



Large Methyl
Isocyanate Storage
Tank Capacity

Union Carbide





Methyl Isocyanate Gas Release Factors

Vent/Stack source height of 33m
Release quantity 40 tons
Release duration 1 ½ hours
Release velocity 88 meters per second

Geographic Factors

Location of plant relative to city
Urban heat island
Presence of lake

Vulnerable, high-density urban population devastated, livestock killed, vegetation damaged over wide area

Local Meteorological Factors

Low wind speed
Low NW wind direction from plant toward city
Nighttime release

Dynamic Factors

Urban heat island trapped release near city
Inversion layer trapped release near ground
Area SE of city (J.P. Nagar colony) worst affected
Copious dense white fumes, last for 5 hours

Bhopal: Meteorological Models

... the impact of the accidentally released methyl isocyanate gas occurred within a small area southeast of the Union Carbide plant. In this area, the gas cloud is confined over the Bhopal city but the return flow of the urban heat island circulation for a significant time period (at least until sunrise).

... the worst affected area was located southeast of the plant (J.P. Nagar colony). This colony was engulfed with copious dense white fumes having a bitter sweet smell. The gas concentration was so high that visibility was very poor. The gas cloud lingered over the J.P. Nagar colony for an unusually long time (about 5 hours after the start of the release), resulting in a large number of casualties by the time the smoky pall was cleared at about 0530 IST (p. 490).

Boybeyi, Z., Raman, S., and Zannetti, P. (1995) Numerical Investigation of Possible role of Local Meteorology in Bhopal Gas Accident. *Atmospheric Environment*. 29(4), 479-496.

BP – A Transdisciplinary Analysis

The transdisciplinary approach to analysis that I have presented can be applied to the BP oil spill.

The supercomplexity of the disaster is made explicit in the first set of slides, and by the Bhopal slides.

B.P.

**Cost Cutting & inadequate
safety procedures caused
explosion on drill rig**

**Human
Catastrophe**

**Large, unstoppable
release of Oil –
Ecological Disaster**

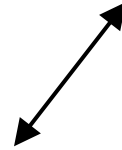
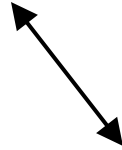
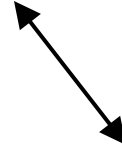
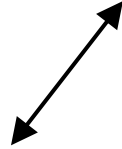
**Ecological
Catastrophe**

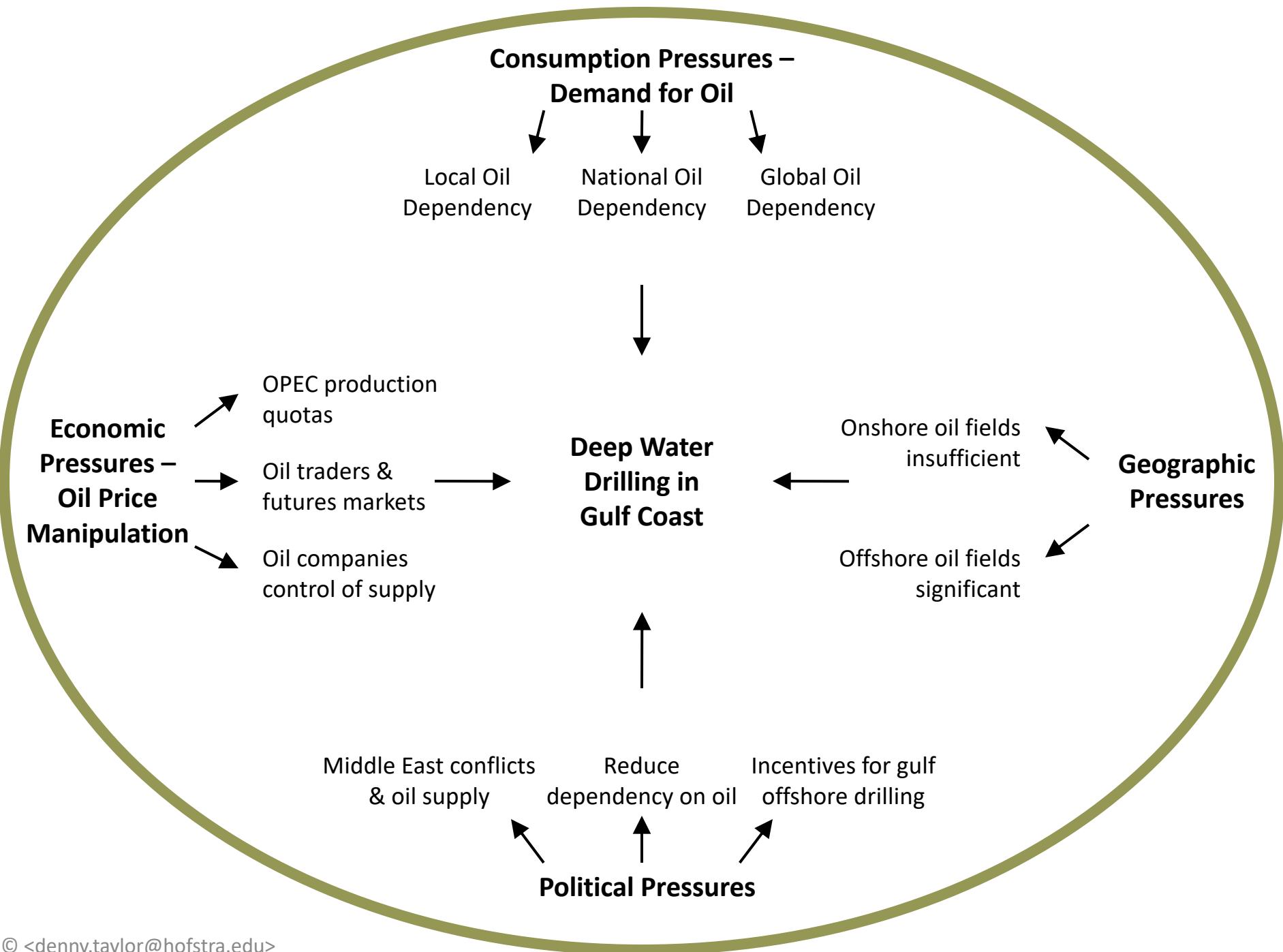
**Lack of emergency
plans & equipment to
deal with failed BOP**

**Deep water drilling
with remote-
operated
equipment**

**Blow Out
Preventer (BOP)
failed to shut –
inadequate
design**

B.P.





Consumption Pressures – Demand for Oil

Local Oil Dependency National Oil Dependency Global Oil Dependency

Deep Water Drilling in Gulf Coast

Economic Pressures – Oil Price Manipulation

OPEC production quotas
Oil traders & futures markets
Oil companies control of supply

Geographic Pressures

Onshore oil fields insufficient
Offshore oil fields significant

Political Pressures

Middle East conflicts & oil supply Reduce dependency on oil Incentives for gulf offshore drilling