Design in the Age of Entanglement

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Director of Graduate Engineering Programs

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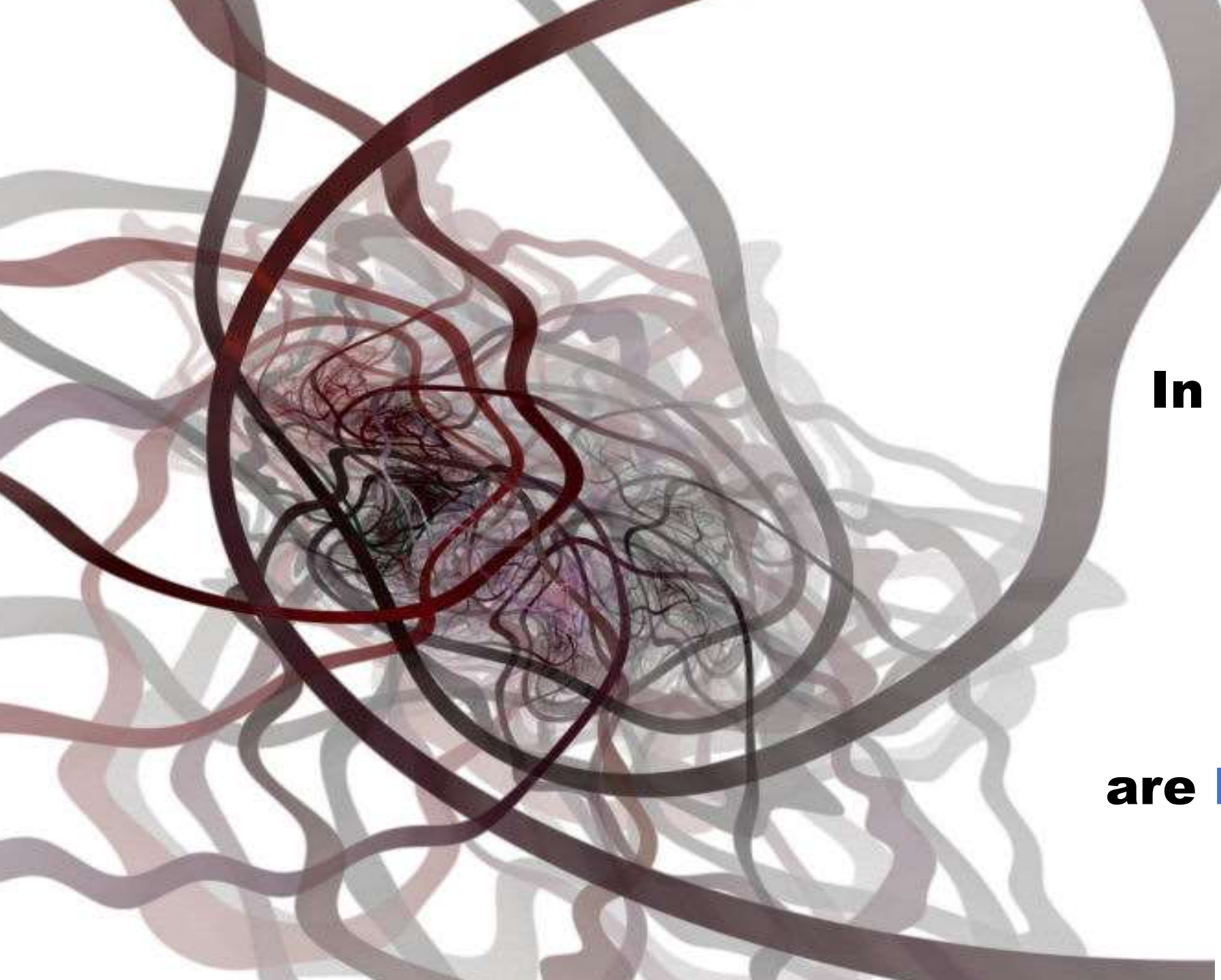
From Enlightenment to Entanglement

- **19th Century** was the age of **Enlightenment**
  - The realms of human exploration and expression
  - Built siloes (Disciplines), both in means and in mindset
- **20th Century** built technologies and solutions mostly based on these disciplines
- **The 21st Century** is breaking away from these notions



In the 21st Century,
Science,
Engineering,
Design
and Art
are Entirely Entangled

Entanglement
Boundaries between disciplines are melting

No more separation between

- Culture and Nature
- Artificial and Organic
- Synthetic biology or Biosystems
- Brain and Artificial Intelligence
- Imaging and Chemical Composition of matter

Connections among Domains of Creativity
Science, Engineering, Design and Art

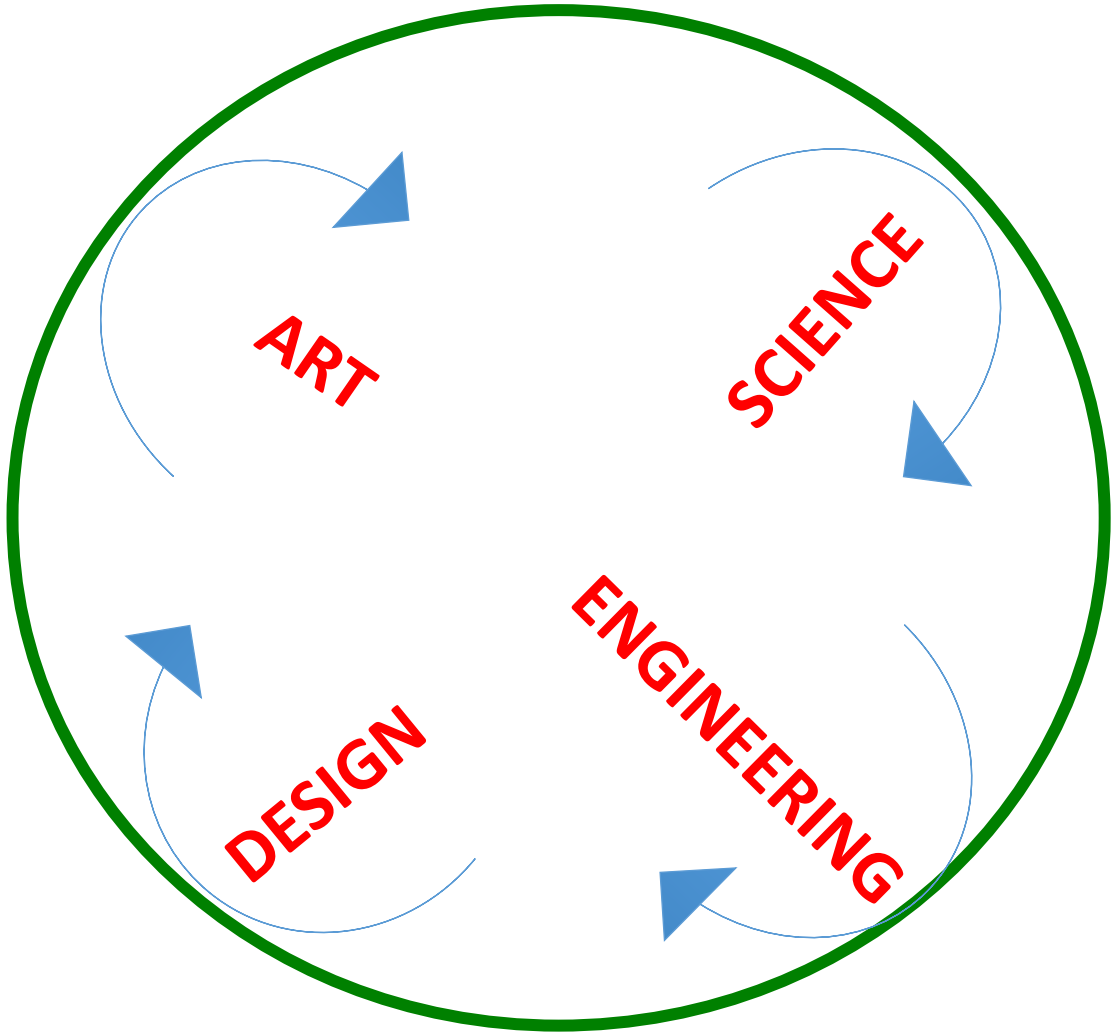
- Science: explore nature
- Engineering: invent & create for humanity
- Design: communicate
- Art: express

Our world requires convergence of these areas

Arts and Science

- Art and Science are human needs to express the world around us
- They offer speculations about our reality
  - Artists produced paintings to make sense of reality
  - Scientists advance hypotheses and proofs to understand reality

Impossible to discern one modality from another



Each of the modalities produces ‘currency’ by transforming into another

20th Century

Impressive Human Achievements

Telephone

Home Appliances

Personal Computers

Radio/TV


Electrification


Spacecrafts


Automobiles


Aviation

Water supplies and Distribution

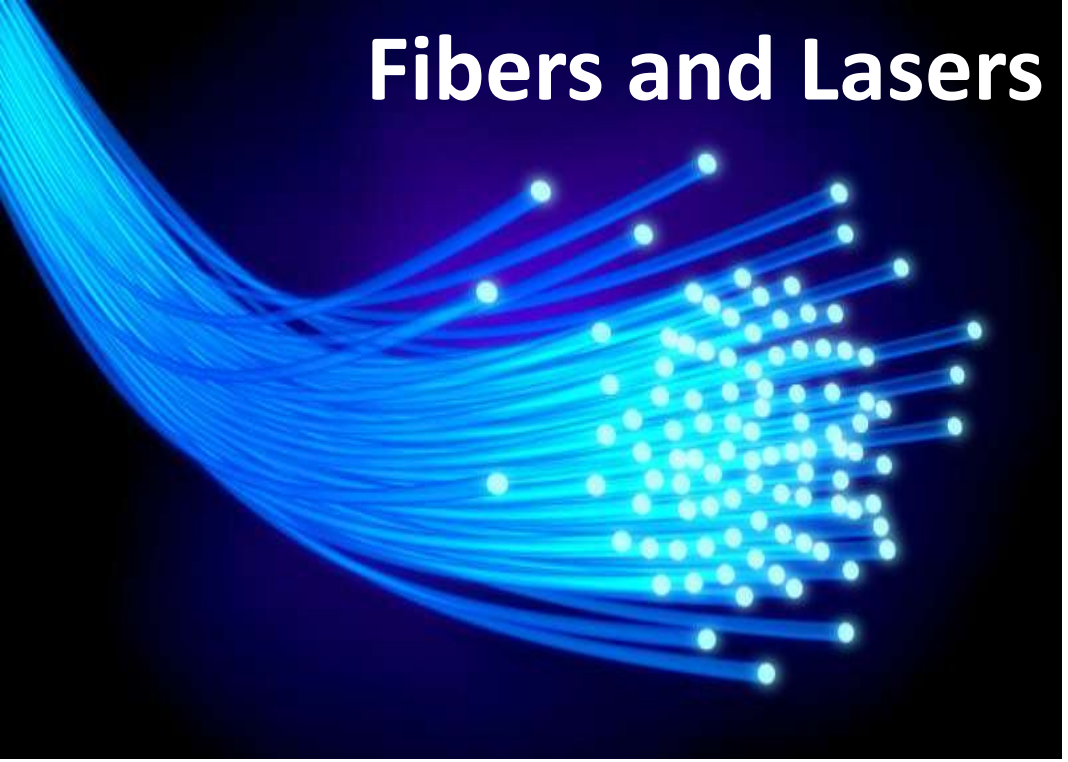
Agricultural Mechanization

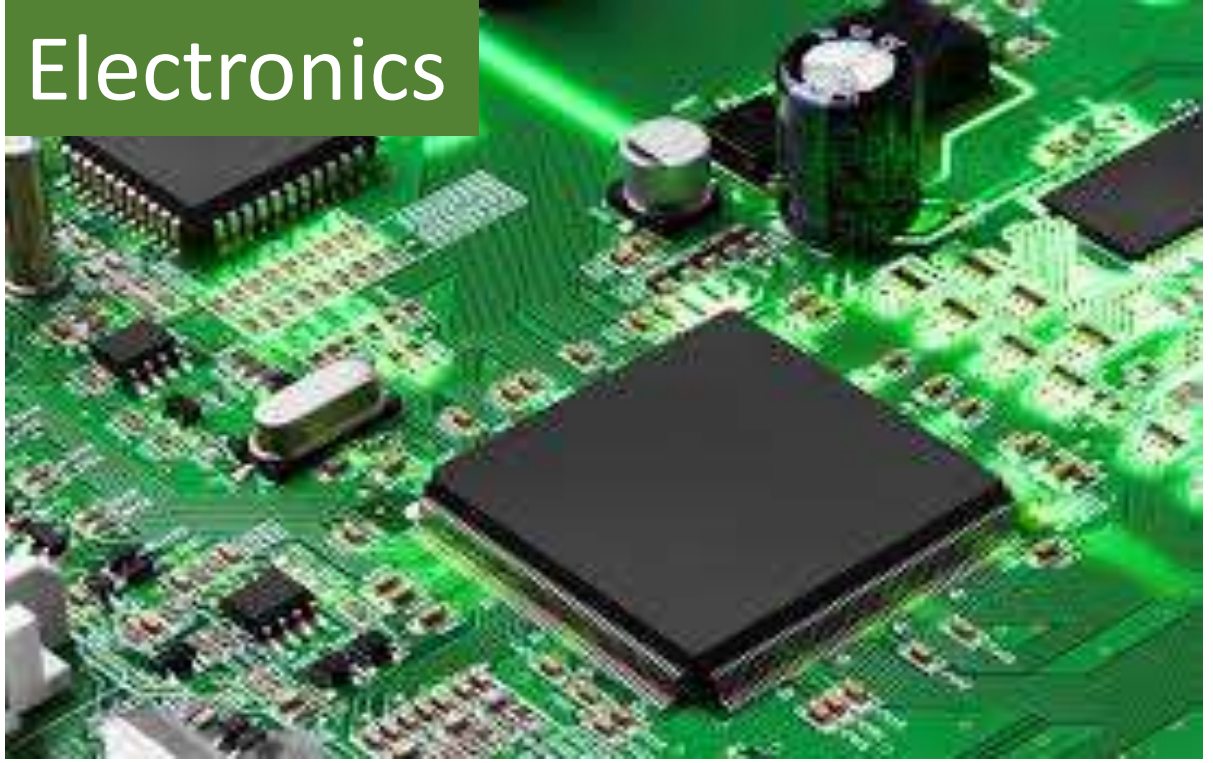
Petroleum Industry

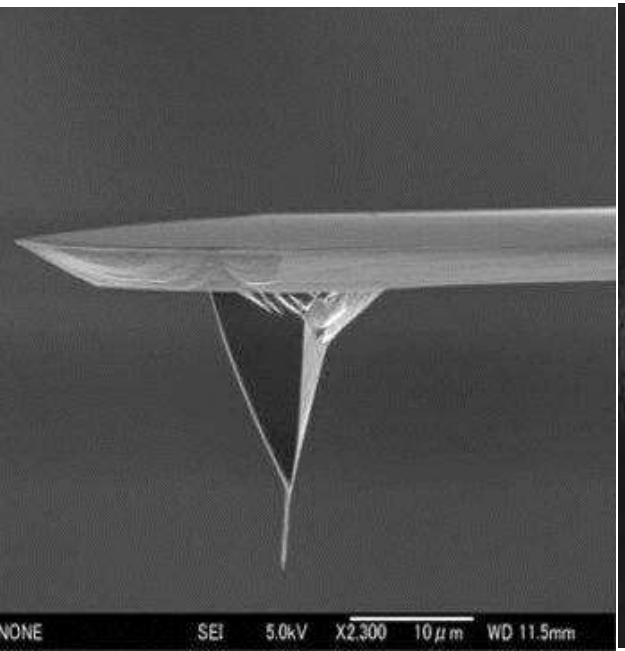
Nuclear Energy

Highways

The Internet


Fibers and Lasers


Electronics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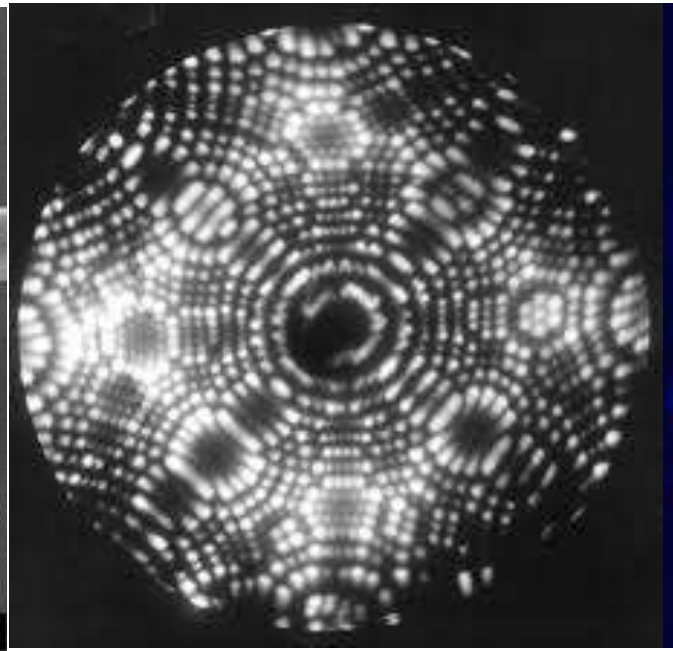
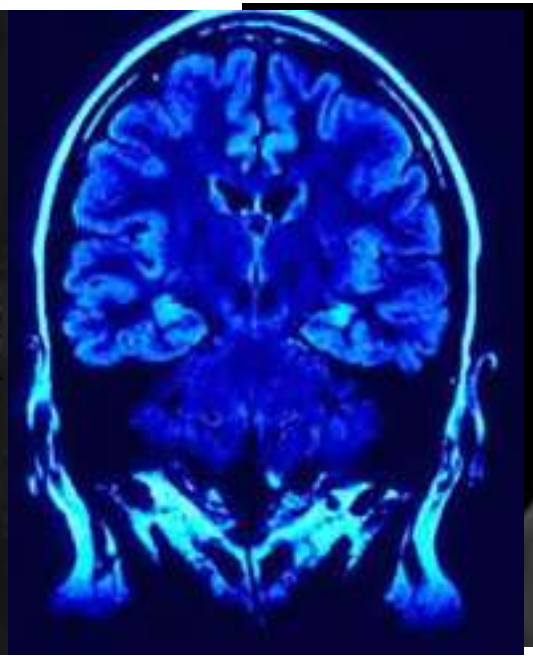
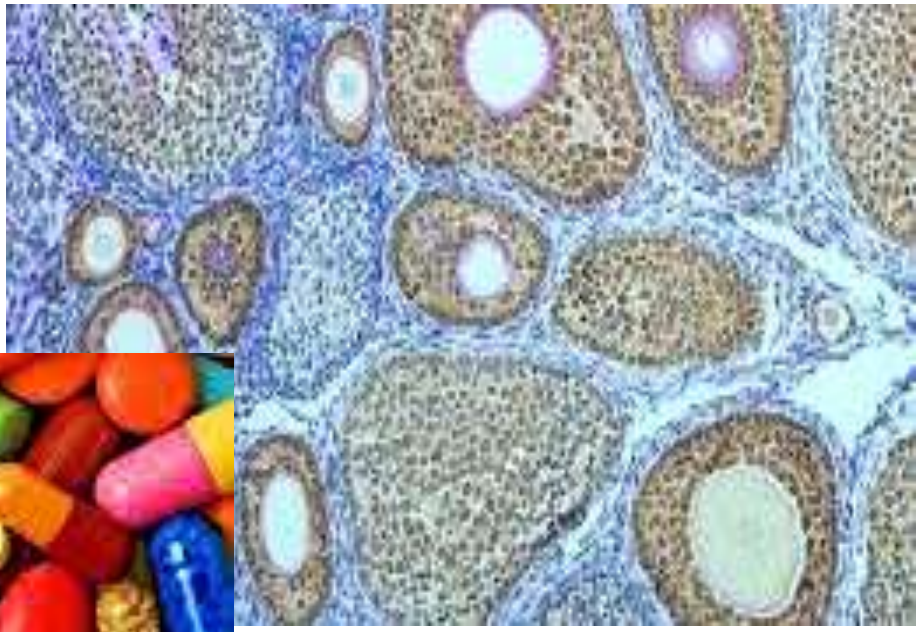
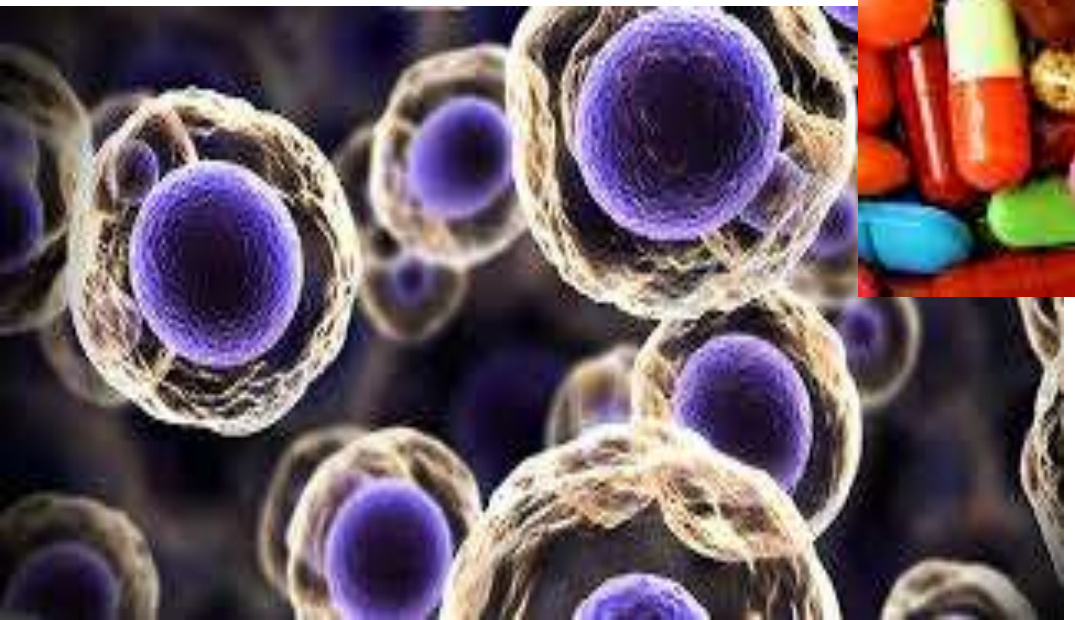


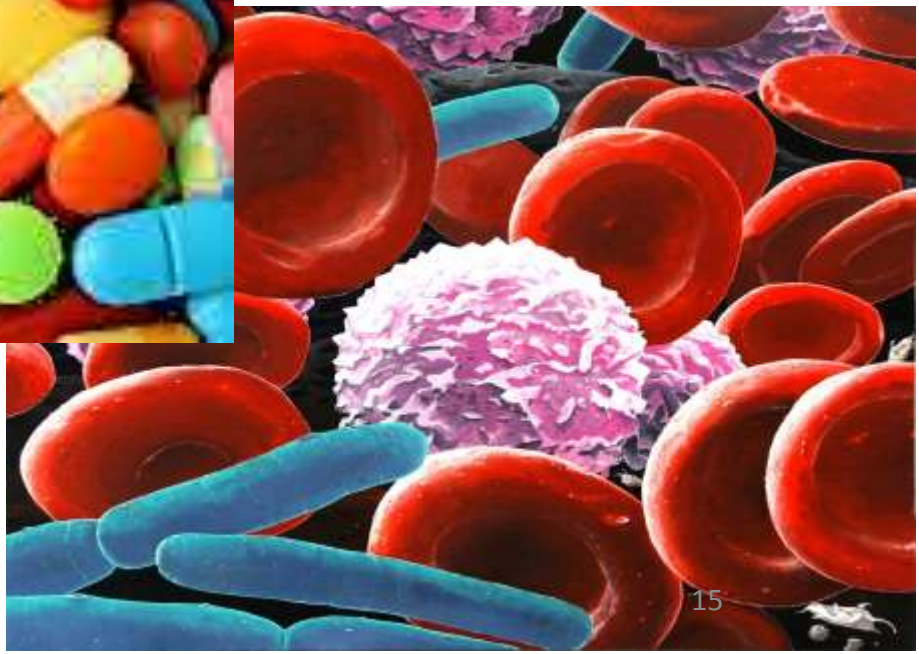



Imaging

Health Technologies







So,… what is wrong?

These successes created many challenges!

What are these Challenges?

- What are the origins of the challenges?
- Can they be removed / mitigated?
- What is the role of the educational institutions?
- Can we create a unified front to mitigate?
- Work at Harvard
- Q: How do we participates as a unified front?

NAE challenges
{http://engineeringchallenges.org/GrandChallengeScholarsProgram.aspx}

- Advance personalized learning
- Engineer the tools of scientific discovery
- Advance health informatics
- Provide access to clean water
- Restore and improve urban infrastructure
- Engineer better medicine
- Reverse engineering the Brain
- Provide energy from Fusion
- Making Solar Energy Economical
- Manage the nitrogen and carbon cycles
- Develop Carbon sequestration methods
- Enhance virtual reality
- Secure Cyber space
- Protect against Nuclear terror

A Broader View

The Sustainable Development Goals

- A deliberative process involved 194 Member States
  - United Nations Resolution A/RES/70/1 of 25 September 2015
- The proposal contained 17 goals with 169 targets covering a broad range of sustainable development issues

Themes:

- End poverty (lack of income and resources)
- Zero hunger
- Reduce inequalities
- Affordable clean energy
- Improve health (increase life expectancy, reduce some of the common killers, reduce pollution)
- Improve education (inclusive and equitable)
- Make cities more sustainable (safe and resilient cities)+
- Protect oceans and forests
- Combat climate change (regulate emissions and promote sustainable energy sources)
- Peace and justice

What do we really **need** (vs. want!)

- Healthy life (minimum sickness)
- Live without fears (security)
- Joyful and meaningful life (mentally rewarded, …)
- Have a livable earth beyond our lives (sustainable earth)

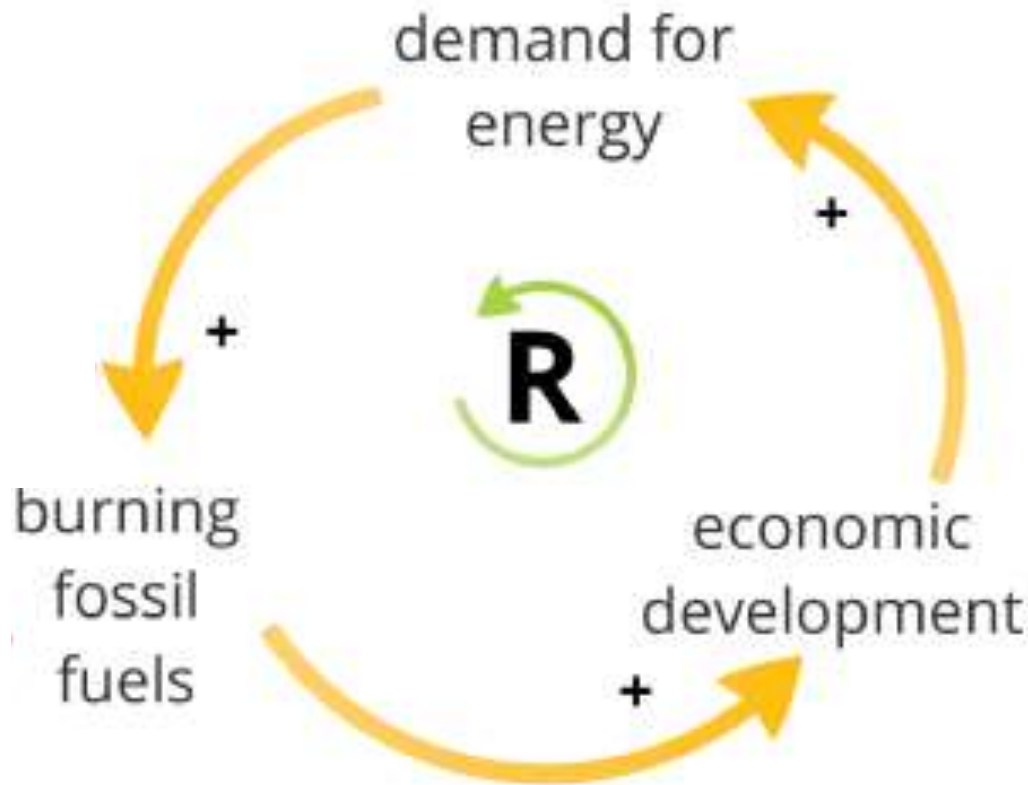
But... To achieve any of these we need to deal with them as systems!

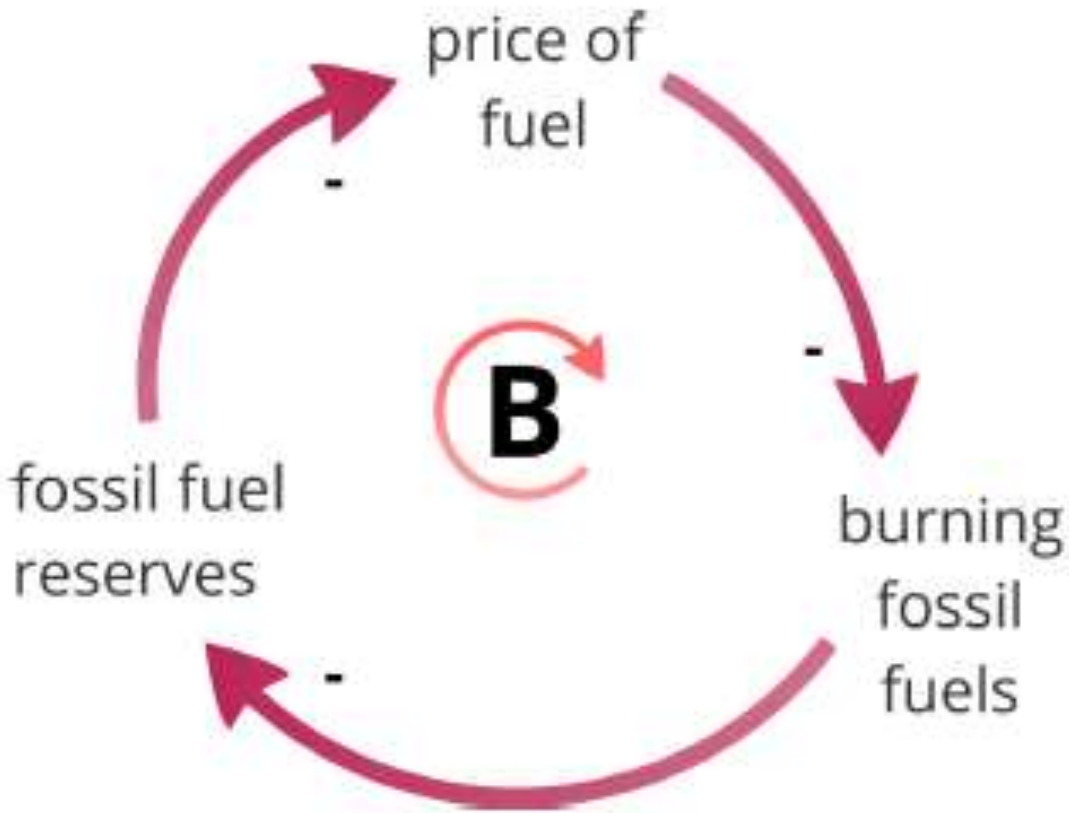
Dealing with Systems – very difficult

- Human design and implementation
- Human interventions
- Human control / Nature control / Autonomous control

Systems are interconnected with Feedback Loops: Complexity

- Human invented technology
- Human nature directed technology
- Technology is affecting human nature
  - Reading changed brain wiring
  - Internet changing human brain, social behavior and how we think


demand for energy
+
+
R
burning fossil fuels
economic development
+


price of fuel
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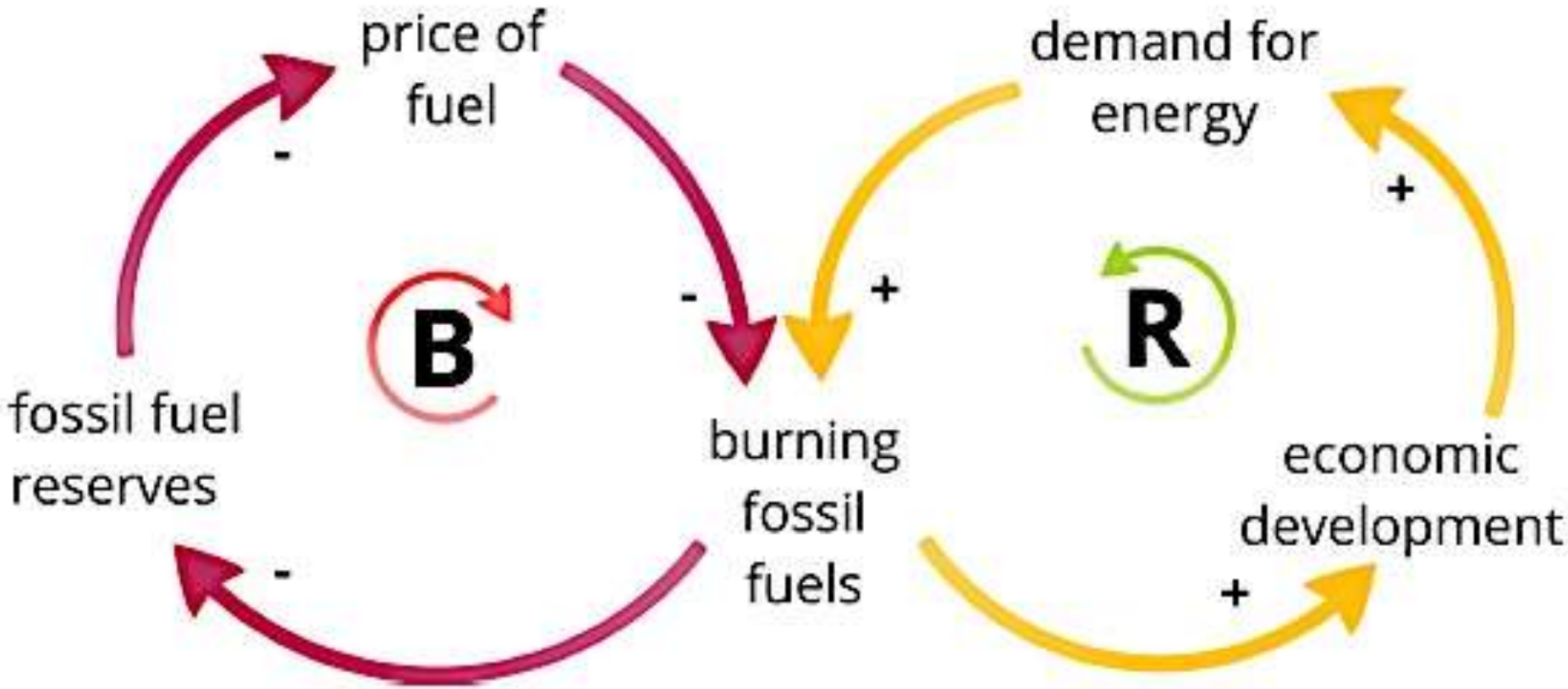
burning fossil fuels
-
fossil fuel reserves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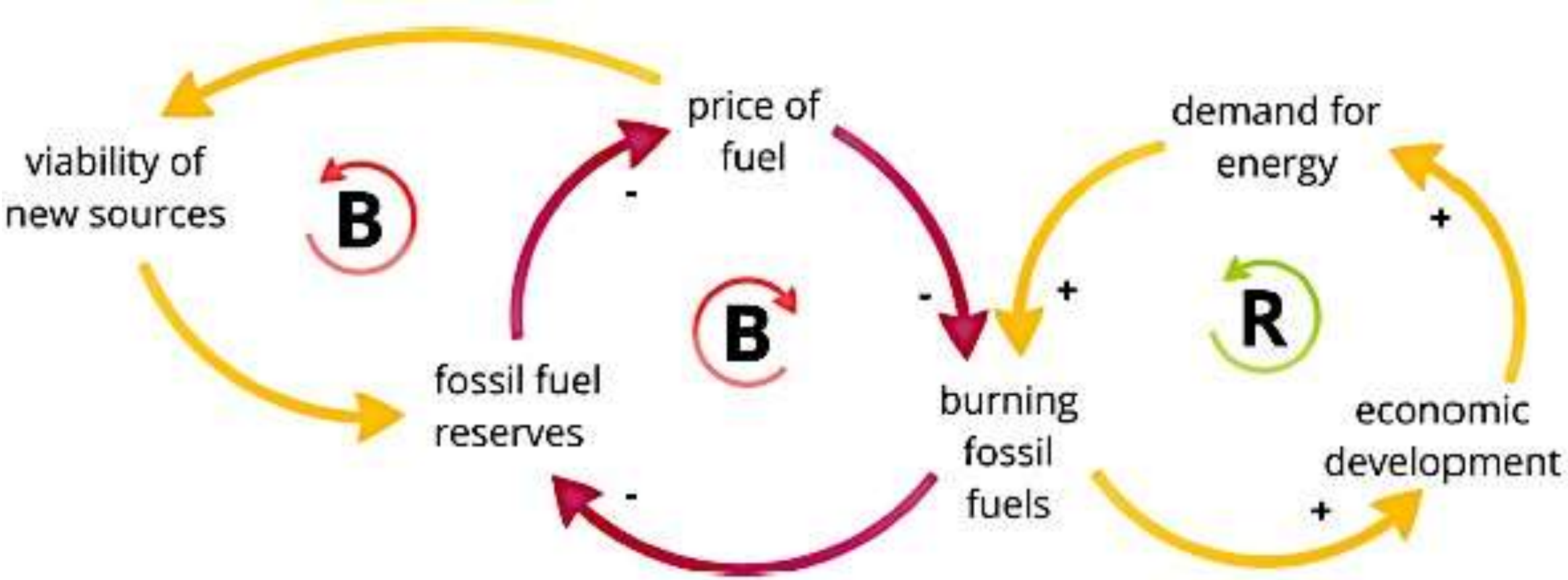


Feedback control loops create dynamic processes
Time delays create significant complexity

Systems Flows

- Each of these flows have **decision points**
- Each of these flows have **action points**

Disciplines in Siloes cannot describe systems and cannot point to decision and action points

Human Goals

Responsibilities as **Educators and Institutions**

Our Responsibility

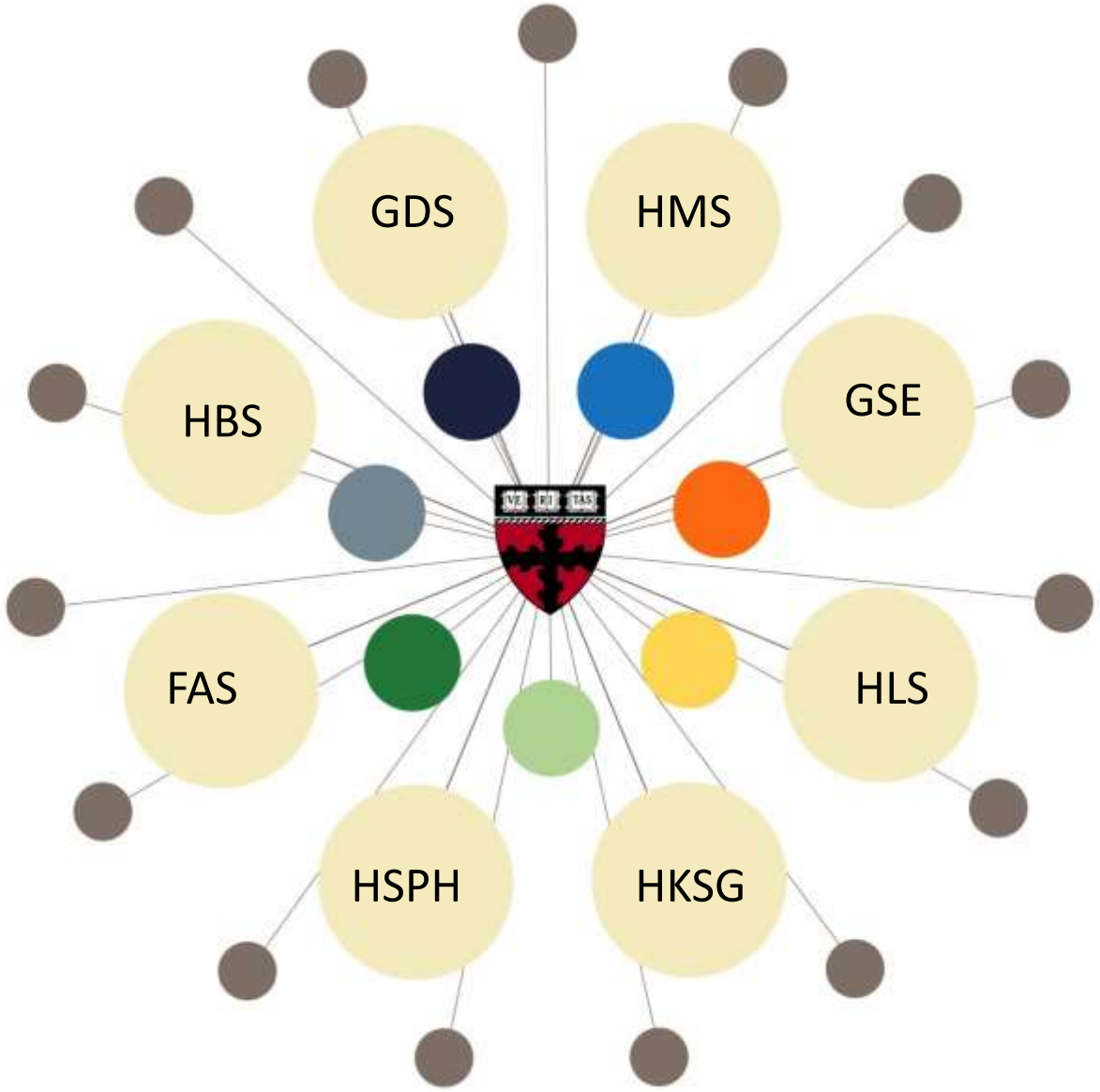
- Through education, we understand the obligations and privileges of living in a free, democratic society.
- Through education we achieve self-actualization.
- Want students to have impact by being
  - critical thinkers
  - creative
  - knowledgeable "a little of everything and something very well."

Harvard is not a typical prototype

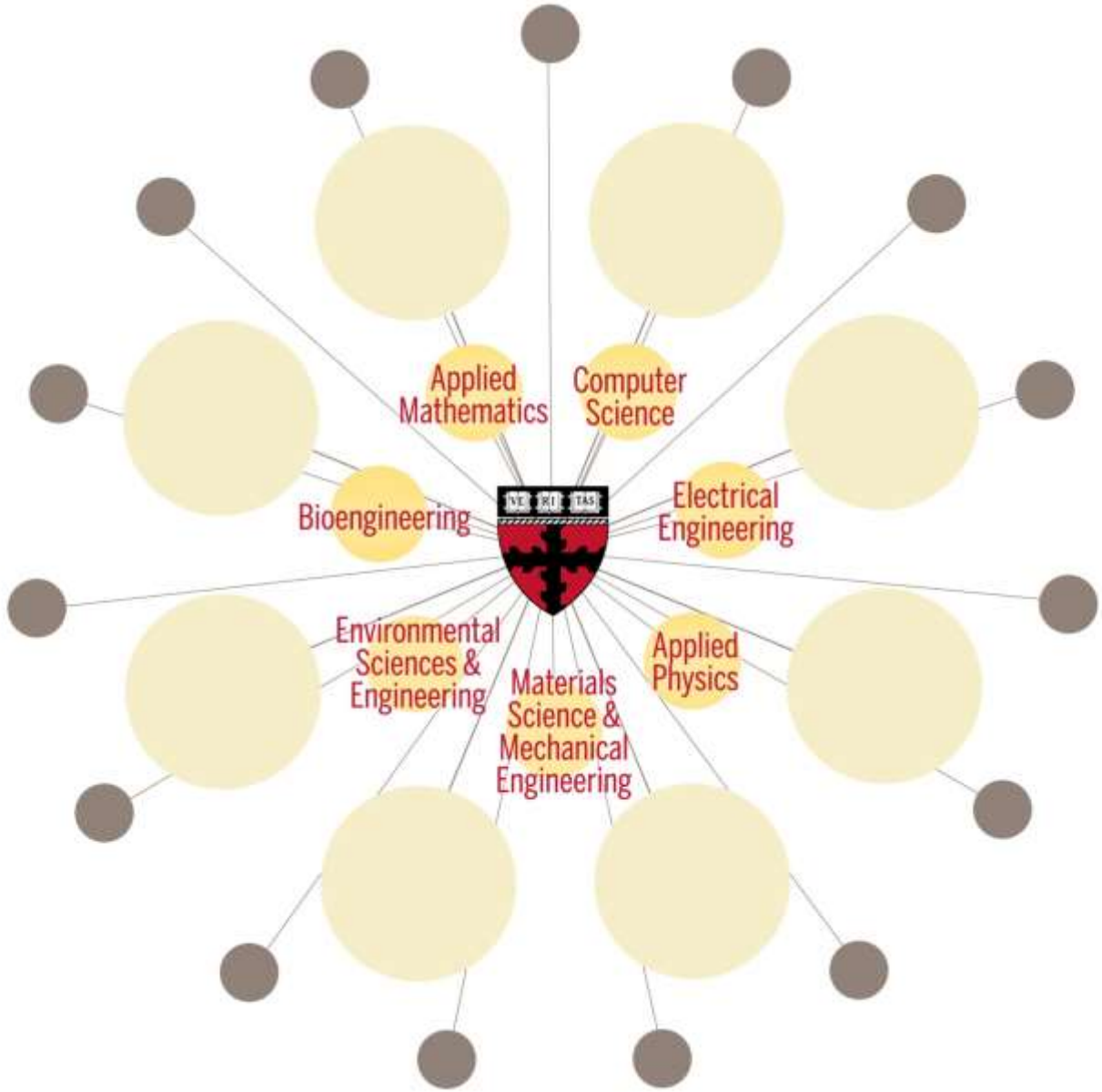
Harvard School of Engineering and Applied Sciences (**SEAS**)

A School with entangled disciplines!

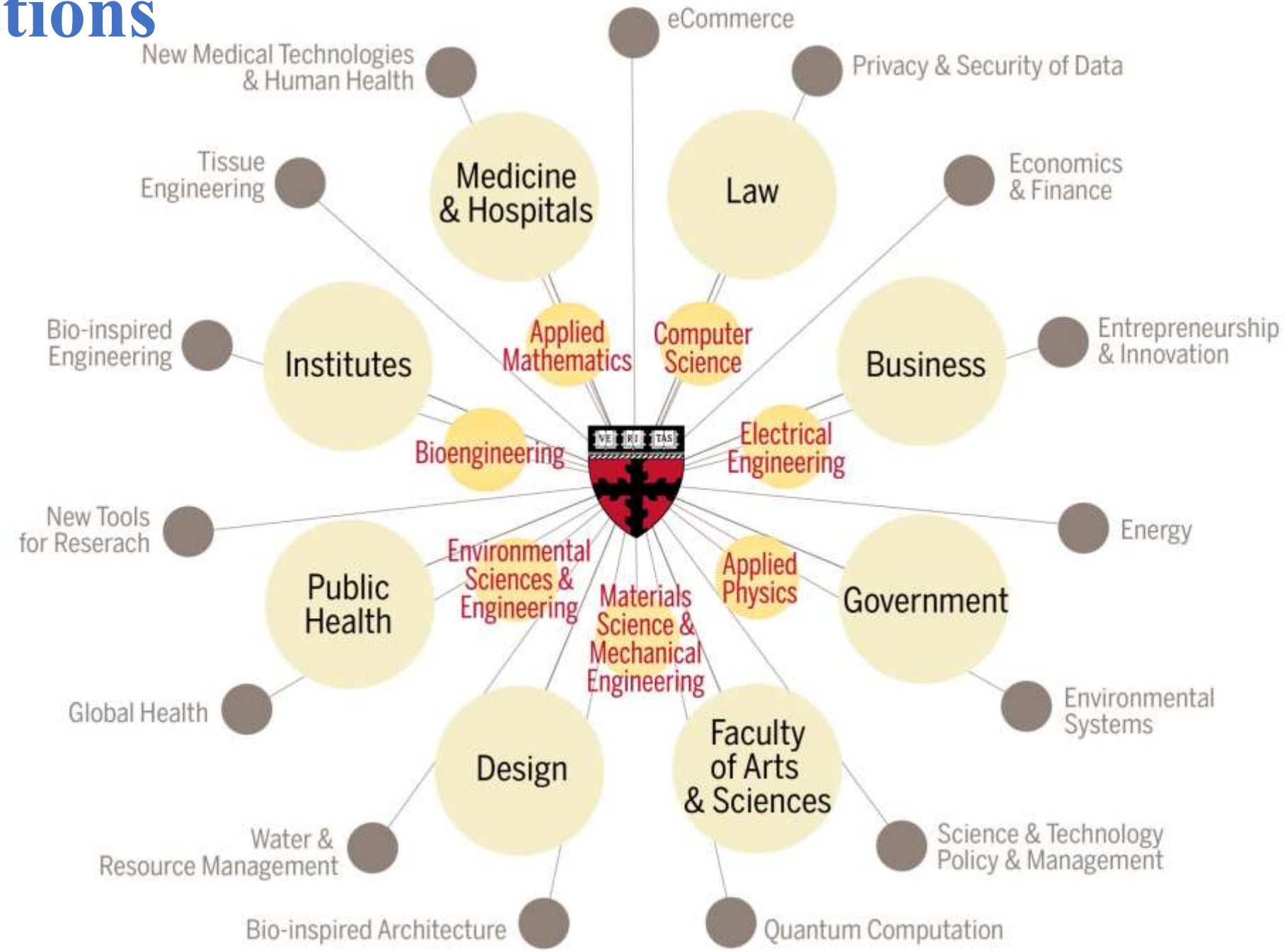
SEAS as Integrator with Harvard



SEAS Academic Areas – no departments



Connections



Engineering within Liberal Arts

Engineering education in liberal arts institutions is different from the purely technical education

- Liberal arts provide students a well-rounded education
- Undergraduate students are required to take general education AND engineering courses (satisfy the ABET requirements)

Connections to human challenges

Horizontally

- Programs for engineering concentrators and non-engineering undergraduate
  - Courses that are related to creativity, problem solving and systems dynamics
  - In addition, there are courses that teach students about entrepreneurship and innovation.

Vertically

- Programs at the masters level

Vertical programs
Master in Design Engineering

- Created to tackle large scale “wicked” problems
- The mission is to train students to address and solve Complex Multidisciplinary Human Problems which involve and span Technology, Economics, Society and Individuals

HARVARD
John A. Paulson
School of Engineering
and Applied Sciences

Harvard University
Graduate School of Design

Master in Design Engineering
(MDE)

A collaborative degree with

Harvard Graduate School of Design

Harvard Engineering and Applied Sciences

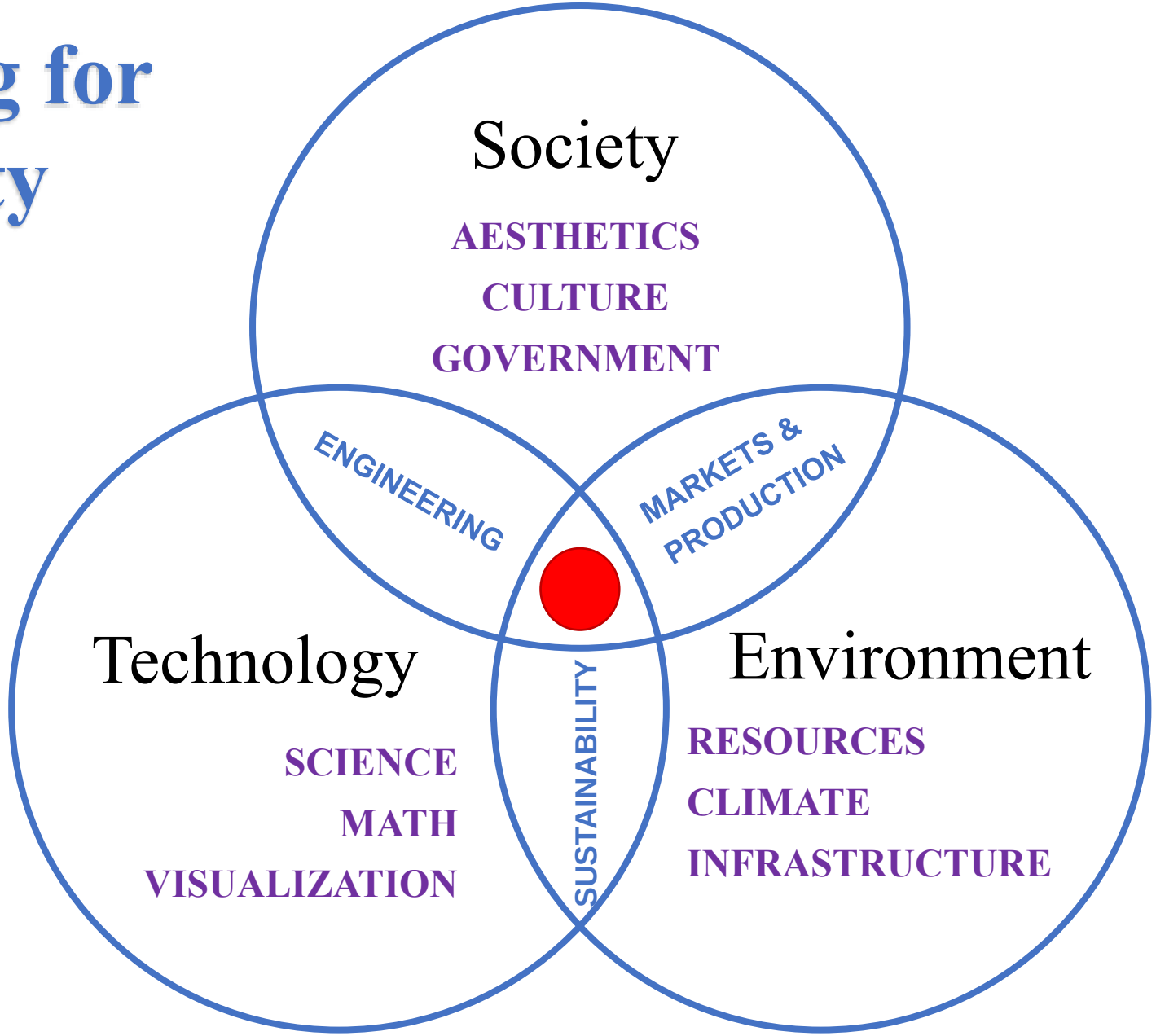
Master in Design Engineering
Academic Oversight

- **Steering Committee**: faculty from both Harvard Graduate School of Design, and Harvard Engineering and Applied Sciences. Active participation from both Deans.
- **Co-directors** from both School, lead the admission committee
- **Advisory Committee** from Industry and Academia

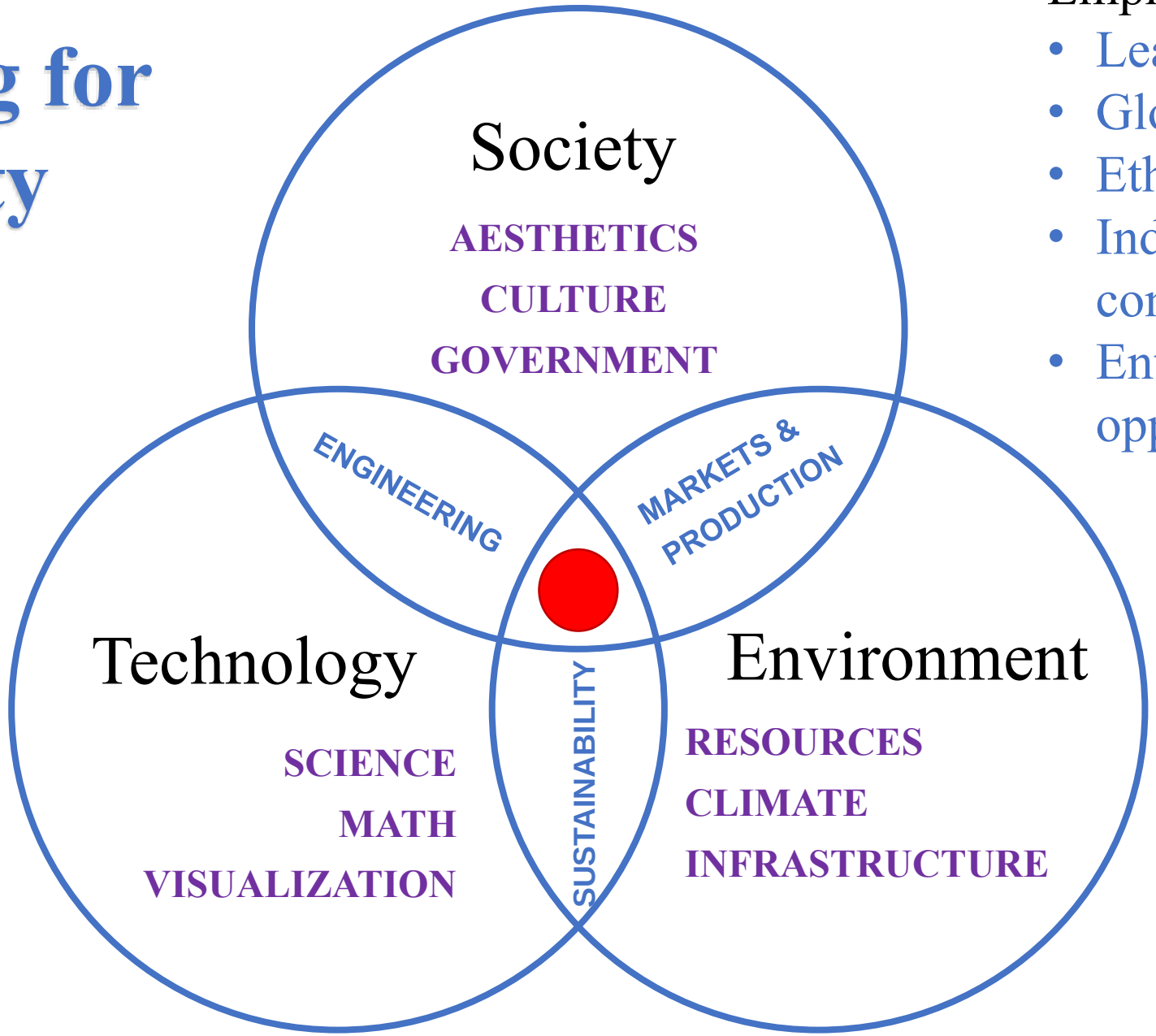
Elements of the pedagogy

- Literacy of innovation: Problem solving through innovation
- Systems solution [design and business thinking, experiences with industry, interactions with clients on a global scale]
- Diversity [knowledge, culture, gender,…]
- Breadth in knowledge and background
- Communication
- Teamwork

Designing for Society



Designing for Society



Emphasis on

- Leadership
- Global collaborations
- Ethical thinking
- Industry/Government connections
- Entrepreneurial opportunities

mde Master in Design Engineering at Harvard

1st MDE Cohort (2018)

- 120 applicants (no advertising)
- 15 Enrolled
- 9 men and 6 women

2nd MDE Cohort (2019)

- 130 applications
- Planned on 20 enrolled

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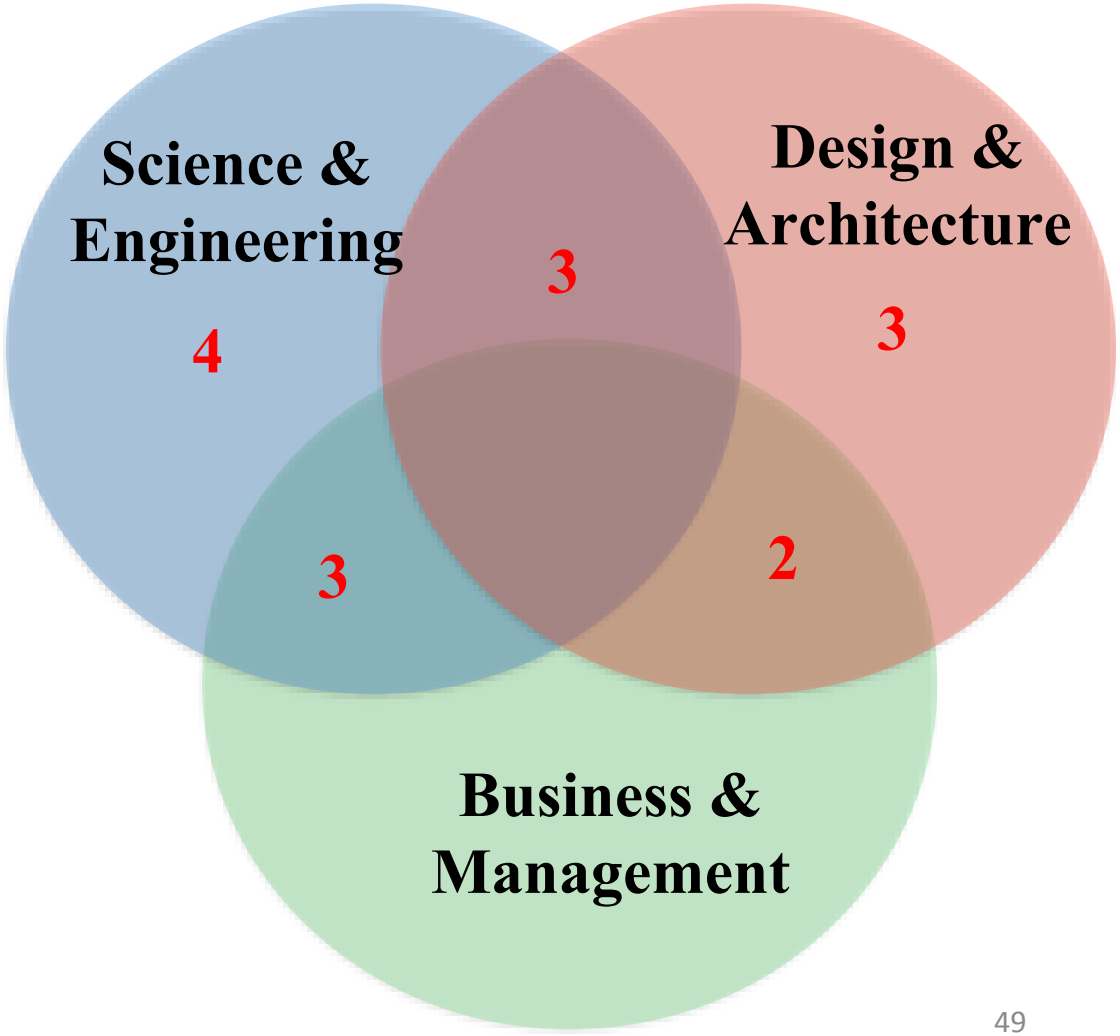

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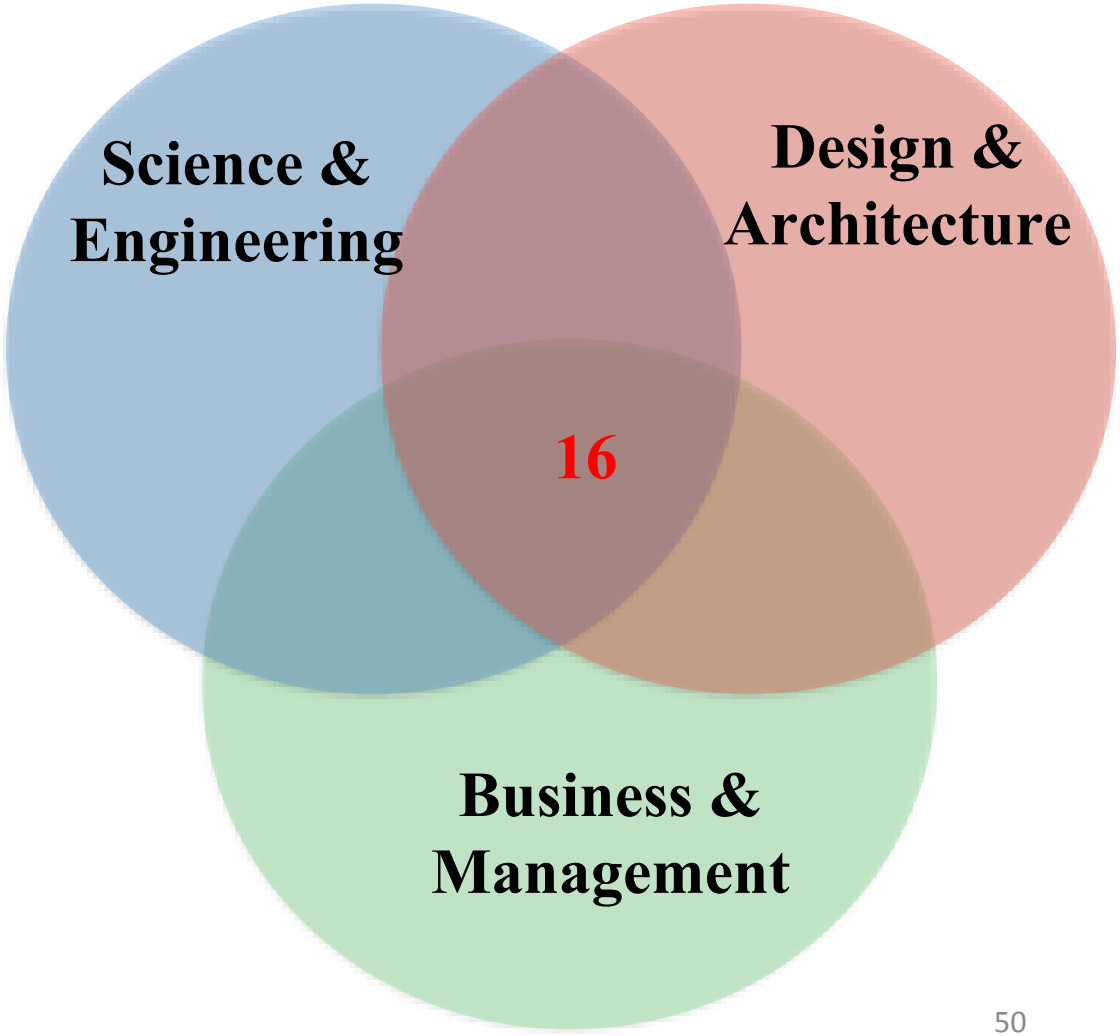
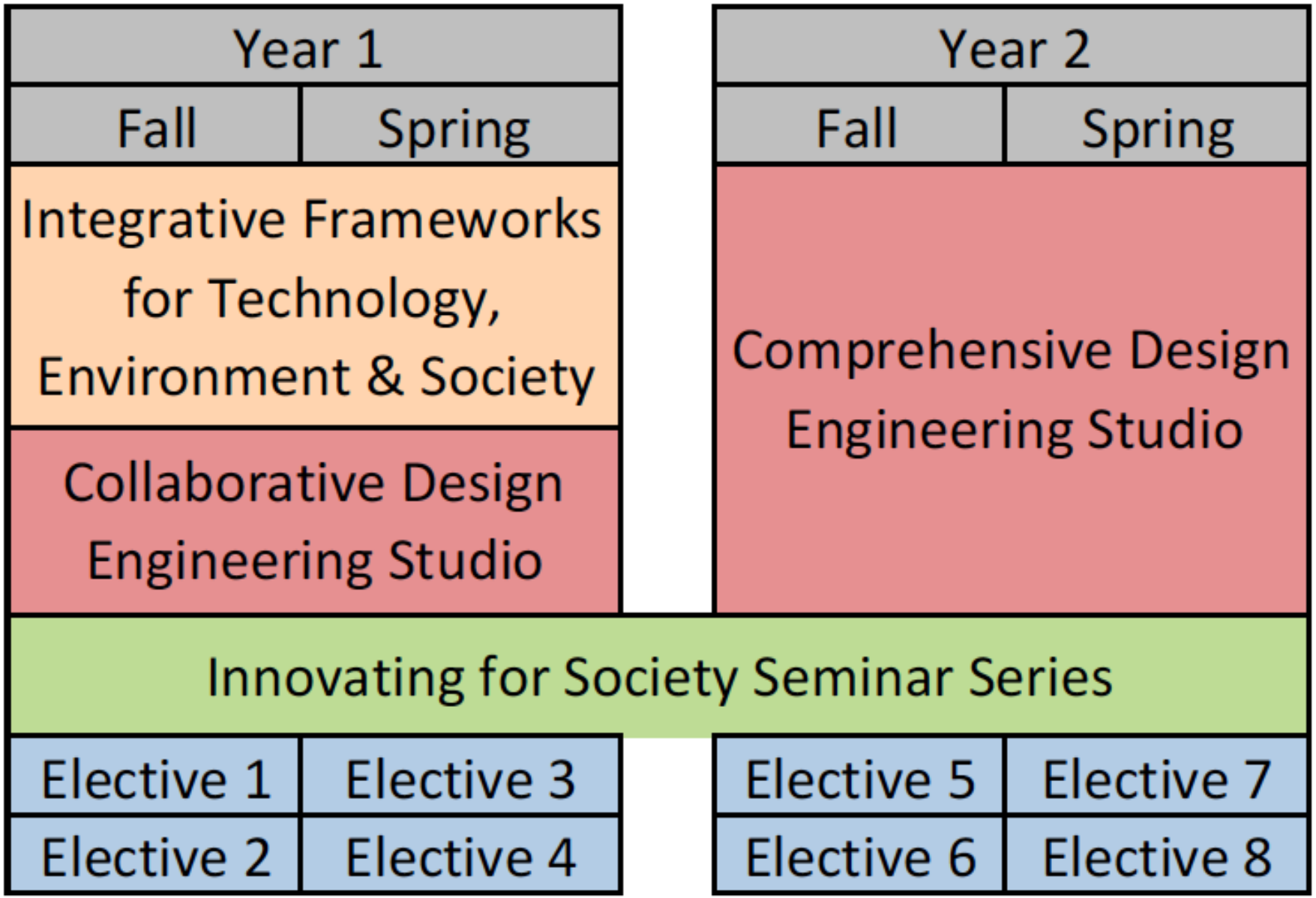


MDE Cohort Origins - 15 Students, 9 Countries

Pedagogy and Curriculum


Year 1
Fall
Spring
Integrative Frameworks for Technology, Environment & Society
Collaborative Design Engineering Studio
Year 2
Fall
Spring
Comprehensive Design Engineering Studio
Innovating for Society Seminar Series
Elective 1
Elective 3
Elective 2
Elective 4
Elective 5
Elective 7
Elective 6
Elective 8

Collaborative Design Engineering Studio

- **2 semesters**
- Group work, State of Knowledge, Analysis Project, Developing Design Brief, and presentations.

- Entire MDE cohort works collaboratively on complex, real world problem involving multiple stakeholders to develop innovative, comprehensive solutions.

Integrative Frameworks for Technology, Environment & Society (2 semesters)

- Design Thinking
- Manufacturing Processes
- Competitive Strategy
- Innovation
- Finance/Accounting
- Intellectual Property
- Technology Transfer
- Government Regulation
- Public Policy
- Aesthetics
- Ethics
- Leadership

2nd year
Individual Design Engineering Project

- Each student works on a project of his/her choice
- Academic advisors from SEAS and GSD
- The Design Engineering Project is an opportunity to deepen knowledge acquired in the first semester, and explore personal interests

The MDE – a master degree, why not a PhD?

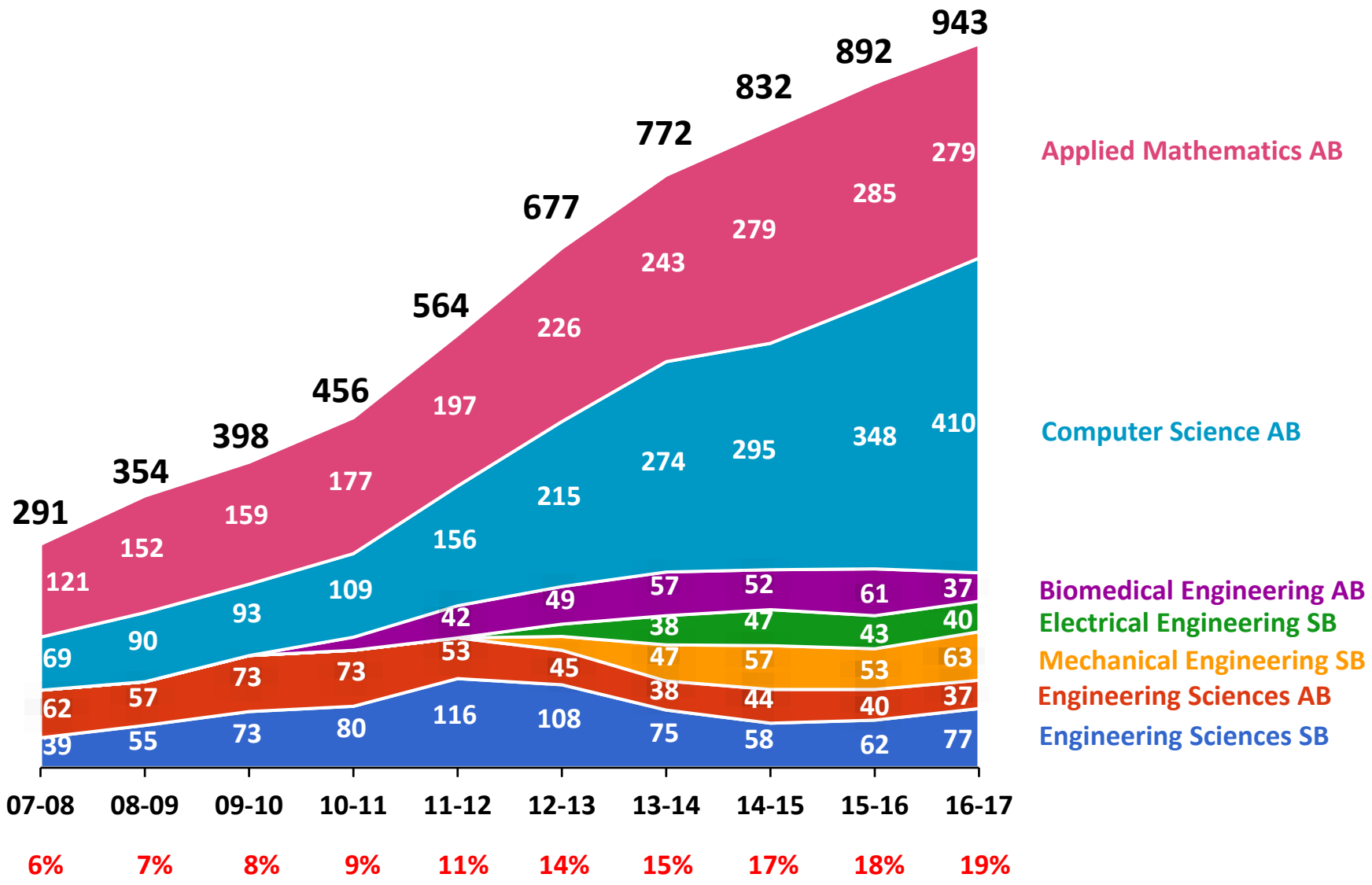
- Any degree is a certification of competency
- MDE is to train People from all over the world in working on Human Challenges
- Graduates are professionals able to address systems issues
- It still requires deep disciplinary learning (8 elective courses), but no particular discipline

The MDE – a master degree, why not a PhD?

- Graduates are professionals able to address systems issues
- Doctoral education (or PhD): advance fundamental understanding or solve a problem (mostly in a discipline)
- Working on Challenges is broader than working on a disciplinary topic, and we do not expect students to create fundamental work, but significant understanding of the overall systems
  - ‘Informing of possible areas for changing the response of the systems and bring a human situation to a much better state’

What about an undergraduate degree?

SEAS Undergraduate Concentrators



Harvard College Students

- 1600 are admitted from a pool of 37,000 applicants
- Allowed to take any class in any order
- Declare ‘concentration’ after 3 semesters
- Must satisfy both

  ‘Gen Ed’ curriculum + Engineering /Applied Sciences curriculum

- Not two students have taken the same courses or had the same path
- Advising is a MUST

In Construction:

A concentration on

Creativity and Innovation

Fill the space between and beyond the disciplines

Value Creation requires Innovation

- Innovation has become a crucial literacy for driving economic, social, and cultural change around the world.
- Never been comprehensively addressed as a trans-discipline, a specific course of study, and in a truly global learning format.

Focus on Innovation

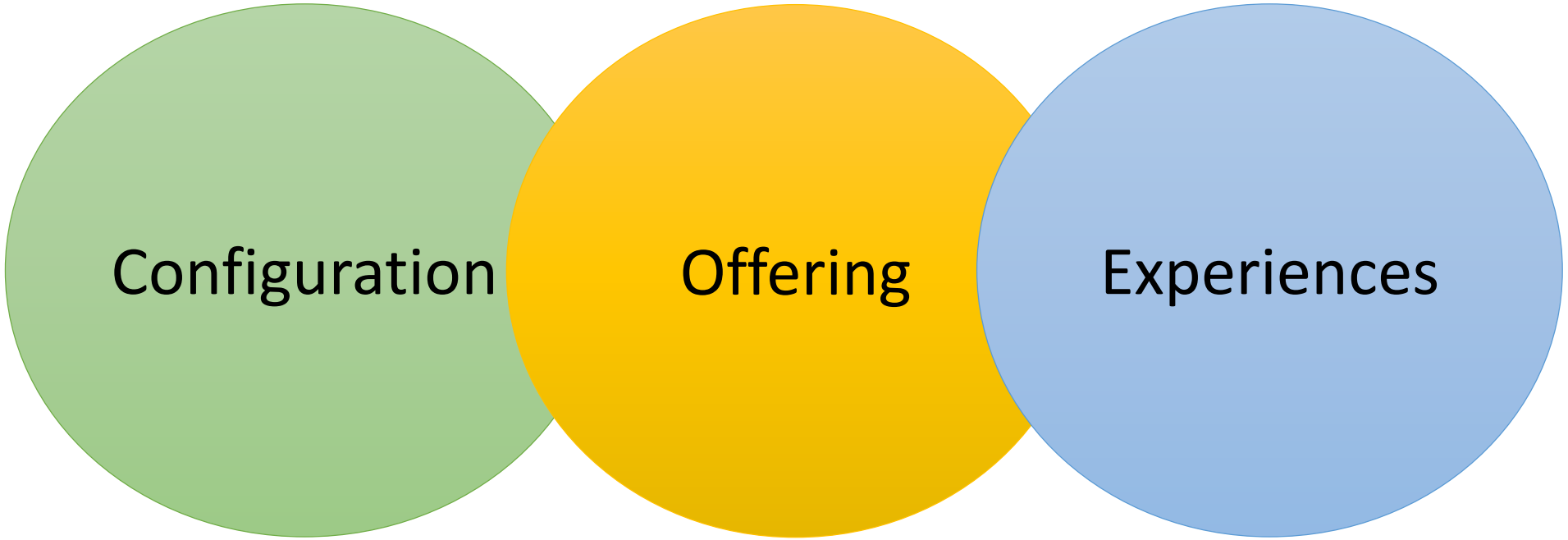
- Purpose is to enable students as interpreters and creators of new value
- Goal is to engender innovative capacity in our students

Provide them with belief in their own agency and an ability to carry it out

Innovation is a broad domain

- Innovation can be defined as: creation of a viable new offering
- **Offering is *more than products***
  - New Business model
  - New systems
  - New engagements
  - Also combination of the above

Innovations Outcomes



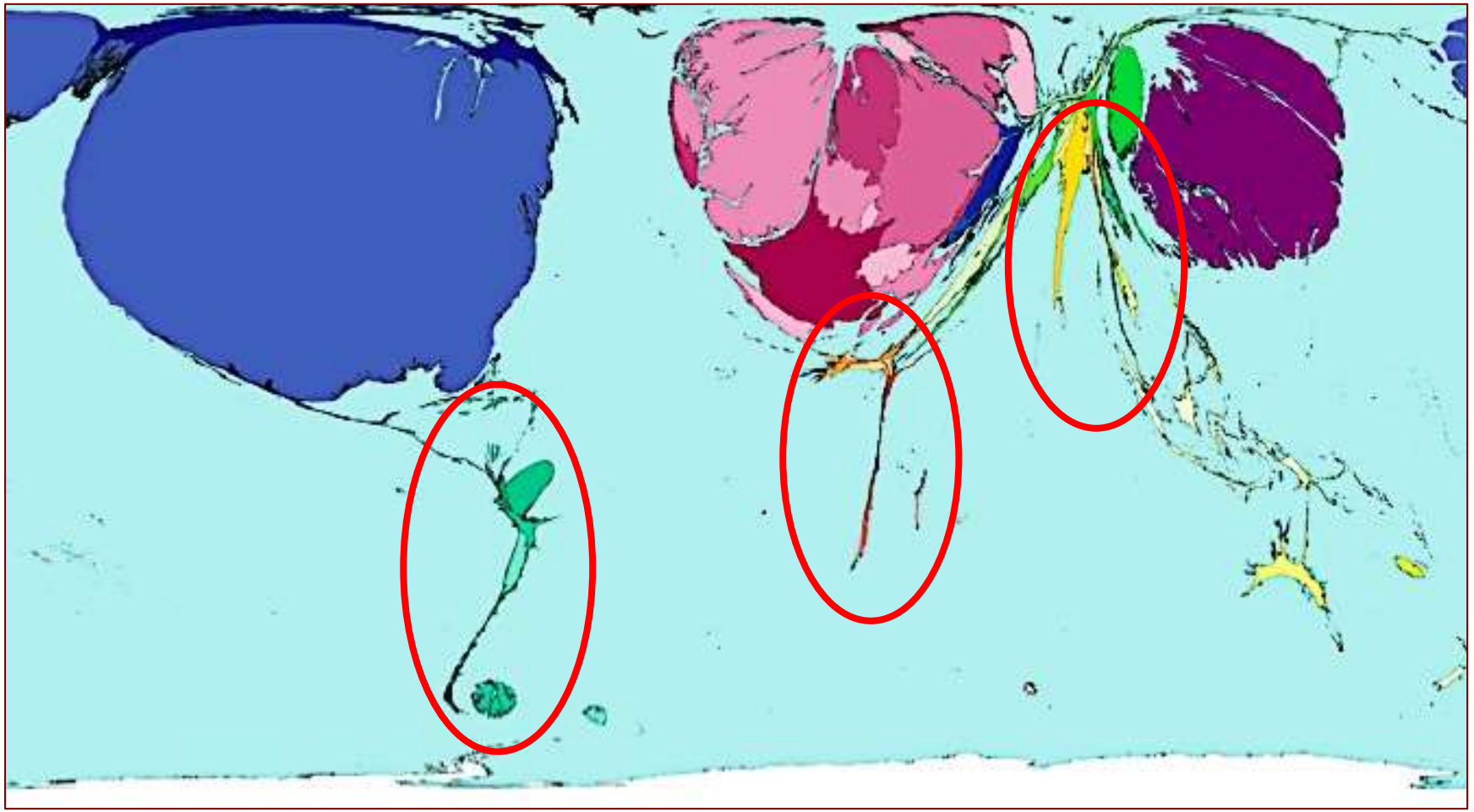
Innovation
lives in the center of entanglement

The world is FLAT

The algorithmic world is flat

But not the innovation space!

The 2016 world as seen from Innovation Capacity



The north-south divide is a socio-economic and political division

Yesterday and today: Fantastic talks.

Need more discussions and collaborations

How can we work together?

Thank you