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The Economic Dynamics of Modern Biotechnology

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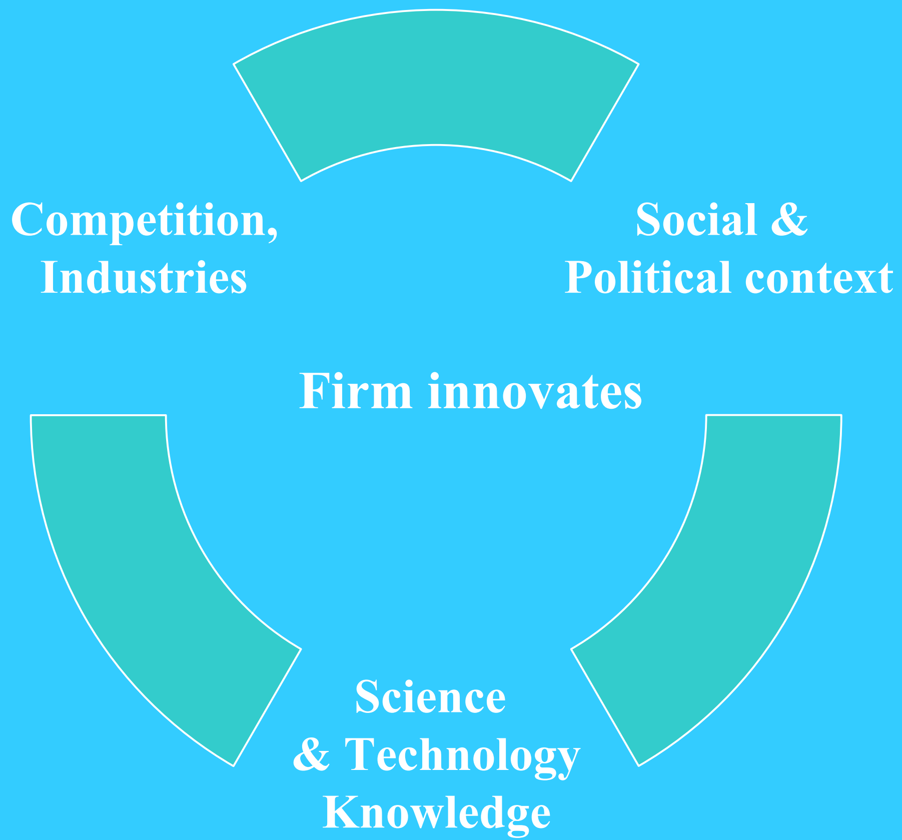
What are the main sources for the talk?

- McKelvey, Rickne, Laage-Hellman (2004). The Economic Dynamics of Modern Biotech. Edward Elgar Publishers, UK.
  - McKelvey (1996) Evolutionary Innovations: The Business of Biotechnology Oxford University Press
  - Various publication in our research group

Research on the economic dynamics of knowledge

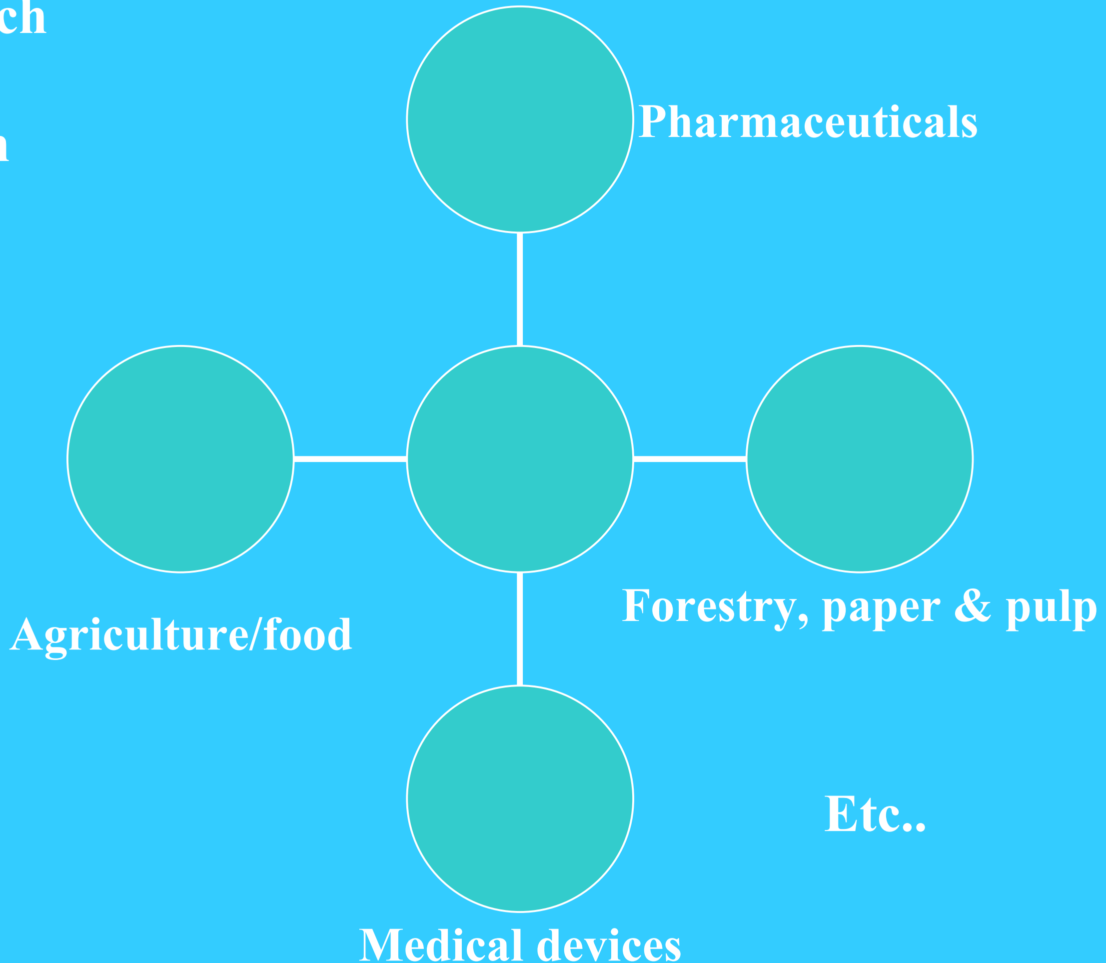
- The economic processes that shape the exploration & exploitation of new knowledge
- How to explain processes whereby
  - Economy is in flux, changing fundamentally over time
  - New products, firms, activities starting up
  - Existing ones being significantly modified or disappearing


Competition,
Industries
Social &
Political context
Firm innovates
Science
& Technology
Knowledge

Economic in the sense of knowledge:

- Is used in such a way that the economy is changing fundamentally– not a return to static equilibrium
  - Affects productive potential (reduce costs; new value)
  - Used in various ways (products in goods & services; new organizations; new relationships/networks)
- Helps create opportunities as 'fuel' for growth

S&T knowledge in modern biotech affects competition in



Modern biotechnology

- OECD 2003 'Biotechnology is the application of scientific & engineering principles to the processing of materials by biological agents to provide goods & services'.
- MB interesting in economic analysis because:
  - Changing, dynamic
  - Broad knowledge fields (various disciplines, new ones emerging, etc.)
  - Useful for many different industries
  - Affects consumers – immediate/long-term

MB Paradoxes (1 of 4)

1. Controveries continue to abound over the negative vs positive societal impacts.

   – Claimed important (industries, large/small firms, human needs)
   – Controversies about potential problems (nature, food, animal welfare)

MB Paradoxes (2 of 4)

2.. Despite controversies over the economic and social potentials of MB, little truly comparative statistics or economic empirical evidence exists.

- Many studies narrowly defined (pharma; only small firms)
- Lack of official statistics – OECD work recent years

MB Paradoxes (3 of 4)

3. Modern biotechnology is at once fundamentally global – and yet, it is simultaneously extremely local in terms of co-located actors

   – Global in terms of the knowledge flows resulting from the movements of skilled persons, ideas, services and products.
   – Agglomeration in particular regions/countries

MB Paradoxes (4 of 4)

4. Modern biotechnology has seemed for several decades to be primarily a US phenomena with the rest of the world lagging behind.

   – Debates whether and why US has competitive advantage
   – Explainations of differences – university research system; in ability to generate and use basic science; commercialize; national institutions; policy.

Given these paradoxes -

- Modern biotechnology is one of many interesting 'S&T knowledge fields' to study
- Because it is/will affect new & existing products, firms and activities.
  - Research questions
  - Methods
  - Results, implications

Research Area 1: How does the firm react and cope with radical uncertainty?

- The firm’s innovative search activities are an investment into the *potential* to innovate.
  - Under technical & market uncertainty

- The firm’s innovative search activities depend on developments in broader environmental factors
  - 1) Competition, industry (Markets)
  - 2) Social & political complex
  - 3) S&T Knowledge development

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What type and level of uncertainty?

- Useful to think of a matrix
  - Two domains of uncertainty:
    - Market vs technical
  - Two degress of change:
    - Radical vs incremental changes

Radical market/ radical technology	Incrementa l market/ radical technology
Radical market/ incremental technology	Incrementa l market/ incremental technology

Example 1 = Glaxo and Combinatorial Chemistry

- Combinatorial chemistry --- especially the use and development of this knowledge
- Technological learning by large pharma

- From Malo, S. (2003) PhD thesis from MERIT/ book; Postdoc at Chalmers & book manuscript

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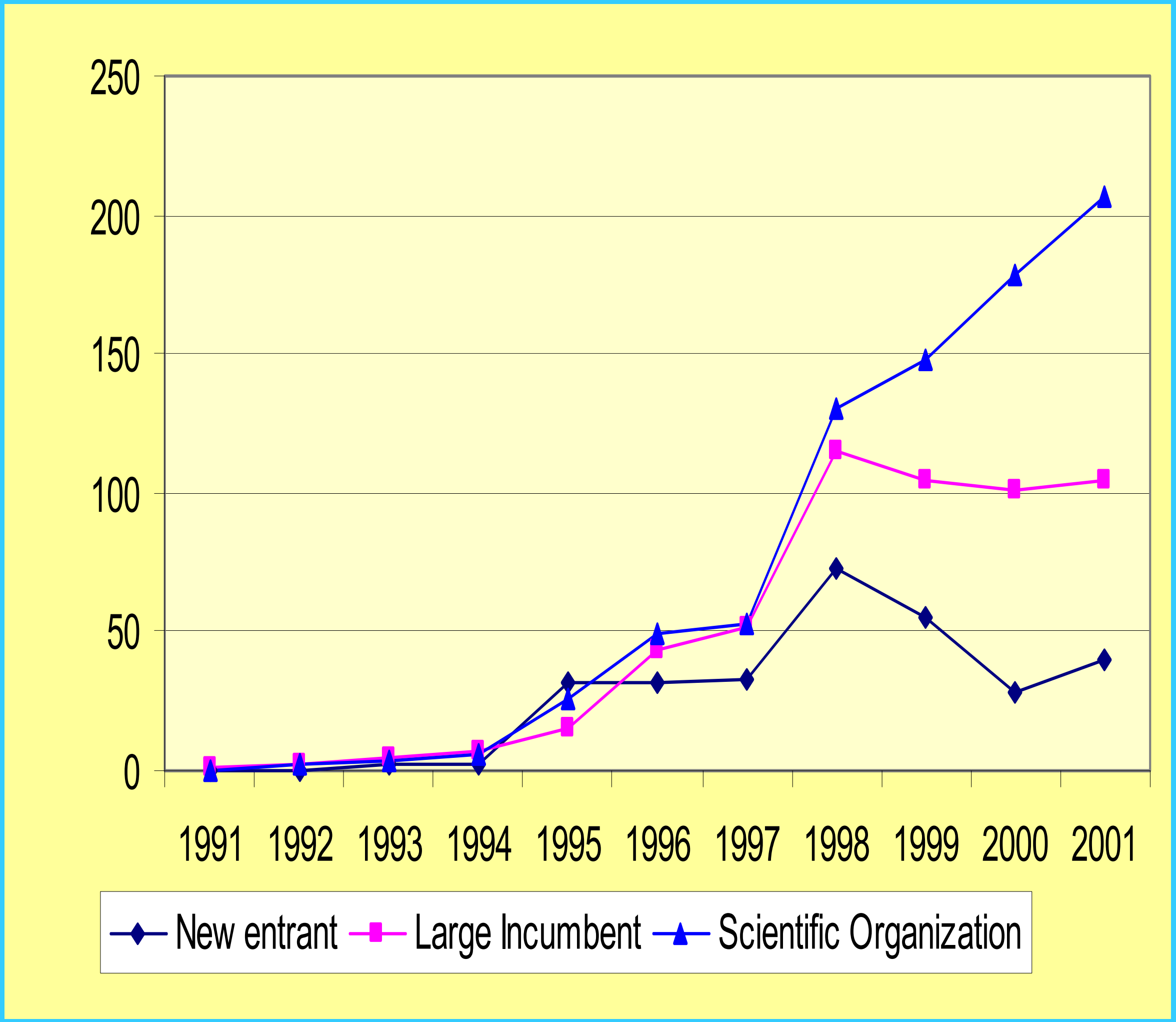
Number of combinatorial chemistry libraries, by type of organization



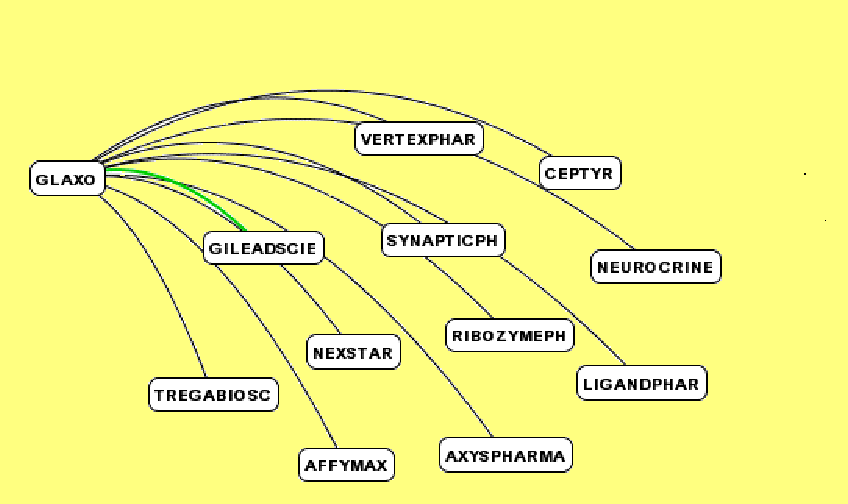
- **New entrants: 297 libraries**
- **Large incumbent: 550**
- **Scientific organization: 802**

GlaxoSmithkline and competence building in combinatorial chemistry (1988-1995)

- **Resistance to change by large pharma (incumbent)**
  - The initial impression essentially was that the technology was not practical and unscientific
- **Opportunity – cost and knowledge**
  - The cost of synthesising molecules dropped from $US 7-8000 to $US 8-12 per unit
  - Before 1995, GlaxoWellcome (now GlaxoSmithKline) had made 350,000 molecular entities since its inception. In 1988, Affymax could synthesize the same number of compounds a year
- **Threat from other firms**
  - First start-ups (Affymax and Coselco Mimotopes) entered the industry in 1988. They were followed by at least 393 entrants

GlaxoSmithkline and competence building in combinatorial chemistry (1988-1995)

- **Learning through hiring**
  - In 1993, Glaxo hired Mario Geysen, the inventor of an important combinatorial method
- **Learning through alliances**
  - Before 1995, Glaxo in-licensed libraries as a way to test the viability of the new synthesis methods



Strategic alliance network (1988-1995)

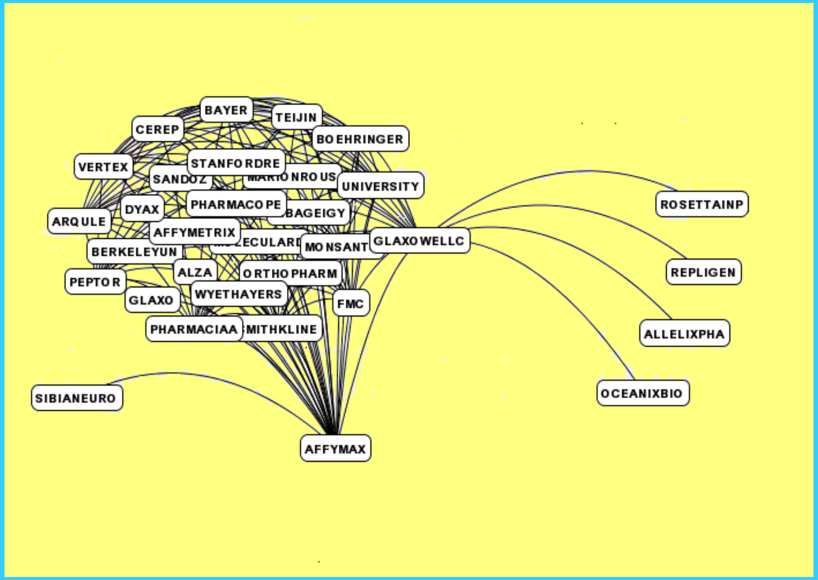
GlaxoSmithkline and competence building in combinatorial chemistry (1995-2002)

- **Learning through acquisition**
  - ❖Once convinced the method could deliver on its promises, Glaxo bought Affymax for $US 539 million in 1995 (yet sold it for $ 51 million in 2001)
- **Learning through training**
  - ❖Glaxo sent scientists at Affymax to learn the skills associated with combinatorial chemistry
- **Learning through R&D --- Routine knowledge**
  - ❖ Since 1995, Glaxo synthesized 81 combinatorial libraries, from which it identified at least 13 lead compounds
  - ❖90 percent of its 400 chemists at its research center at Stevenage, UK, routinely apply the methods

GlaxoSmithkline and competence building in combinatorial chemistry (1988-1995)

❑Learning through alliances

❖After 1995, GlaxoSmithKline was more concerned about improving its research productivity and/or filling its innovation gap. It began leveraging its absorptive capacity in the area to form research partnerships with, and in-licensing drugs from, new entrants



Strategic alliance network (1995-2002)

How does Glaxo cope with uncertainty ?

- **Technological learning**
  - *The process that allows the firm to create knowledge and enhance, expand and renew its competences as a response to environmental changes*

- **Example 1 shows that large pharma used:**
  - **Internal learning**
    - Learning though hiring
    - Learning through training
    - Learning through R&D – routine knowledge
  - **External learning**
    - Learning though alliances
    - Learning through acquisitions

So - how to interpret firms actions under uncertainty?

- Dynamic process - Testing, experimententation
- Strategies depends on tensions in perceptions:
  - Limitations of firm competencies vs new visions of opportunities
  - Symmetry between firm’s markets and initial applications perceived
  - Firm needs perception that market and technical benefits outweigh the risks

Research Area 2: Explaining the public-private dimensions -- that affect the exploration and exploitation of knowledge

Examples can be given through re-visiting
the 4 paradoxes of the
economic dynamics of modern biotechnology

MB Paradoxes (1 of 4)

1. Controveries continue to abound over the negative vs positive societal impacts.

Government regulation affects:

- Risk taking & competence building for the use of genetic information in insurance industry
- Life science informatics experimentation

Example: LION (Ch 9)

- UK integrated informatics company
- No clear division of labour between public & private
- Instead
  - Stage 1 formation – startup through public funds, state support
  - Stage 2 – integrate informatics with other fields; becoming a firm
  - Stage 3 – competitiors; Try to consolidate, alliance
- LION ability to use/develop knowledge for economic gain changes dramatically over time

MB Paradoxes (2 of 4)

2.. Despite controversies over the economic and social potentials of MB, little truly comparative statistics or economic empirical evidence exists.

- MB as more than pharma – agri-business, medical devices
- Detailed data sometimes provide surprising results

Example: Sectoral dynamics (ch 5)

- European countries differ in whether they are specialized in biopharma, agri-food, or equipment & supplies
- Example of France
  - Strongest position in biopharma & agri-food
    - Skills, industry, suppliers, demand (although some opposition to GMOs)
  - Significant research in equipment & supplies

Example: Europe/sector (con't)

- Different industries have different competitive basis – so specialization can affect growth
- Specialization thus affects the national/ sectoral innovation systems, through:
  - Network of knowledge/skills
  - Networks of industry/supply
  - Demand & social acceptability
  - Finance and overall industrial development

Example: Agri-food (ch 7)

- Lactic acid bacteria (LAB)
- Public research as essentially exploratory, anticipatory
- When become commercialized, other countries took over the lead
- Multiple applications
  - R&D networks in unconnected systems
  - Large firms (Unilever, Nestlé, Chr Hansen) as key patentees – but also creators of networks

MB Paradoxes (3 of 4)

3. Modern biotechnology is at once fundamentally global – and yet, it is simultaneously extremely local in terms of co-located actors

   – Region important to start-up phase – not necessarily to later competition

Example: Firm formation (ch 11)

- Biomaterials in Ohio; Massacheusetts & Sweden
- Regional networks of scientists, financing is crucial for firm formation
- A few key actors --- thereby concentration in activities & regions
- Inventor group retains tight relationships with the business venture
- However – some regions have strong scientific interactions; others are isolated islands.

MB Paradoxes (4 of 4)

4. Modern biotechnology has seemed for several decades to be primarily a US phenomena with the rest of the world lagging behind.

   - Huge diversity within Europe
   - Need to research effects on the developing world

Example = Clinical Genomics Firms (ch 3 & Laage-Hellman 2004)

- European research; commercialization in new fields --- but significant difficulties in selling the ’product’

- 3 firms specialize in human genetic studies
  - DeCode;
  - Oxagen;
  - UmanGenomics
- Obtain access to biobanks
  - structured collections of human biological material, such as tissue specimens, blood samples and extracted DNA.
- Difficulties in ’selling’ the information, services, & products
  - Choose wrong knowledge field?
  - Common problem to all firms or especially common misktake in Europe?

How to understand modern biotech?

- Assuming S&T knowledge is useful to transfer a resource into something else, through
  - Knowledge
  - Techniques
  - Instrumentation
- Ability to use knowledge matters because
  - Affect productivity; sales/profits; firm growth; national competitiveness

RA1: Why understand firm – in the broader context?

- Industries are made up of firms
- Broad diversity of firms able to use new knowledge
- Firm acting and doing within dynamic competition process
- Firm facing market and technical uncertainty sees opportunities – and threats

What do examples tell us about firms?

- Competing firms have a variety of strategies and acions
- Firms must 1) identify, 2) learn about, 3) further develop and 4) use knowledge in production and products.
- But, mainly, the firms must reassess these strategies over time
  - Because costly
  - Because on-going R&D
  - Because on-going science and technology

RA2: Innovations within the public-private dimensions

- Innovations - novelty of (potential) economic value
- *Innovations may be*
  - introduced into the market as a product (goods or service)
  - used within the firm/organization as process and organizational changes to increase productivity and product quality.

Modern biotech as an economic phenomena

- Review of existing literature suggests that economic dynamics of knowledge affects more than ’supply/demand as such:
  - Needs to be conceptualized
  - But, any one issue can be turned into a more specific research question.

Four Stylised Facts about Modern Biotech

1. Innovations emerge from uncertain, complex processes involving knowledge and markets

2. Economic value is created in many ways – globally and in geographical agglomerations

´Stylised Facts'

3. Various linkages exist among diverse actors in innovation processes, but the firm plays a particularly important role.

4. Regulations, social structures and institutions affect on-going innovation processes as well as their impacts on society.

COMPLEX PROCESSES (SF1)

- The development of science and technology goes hand-in-hand with the development of applications and markets.
- Each have internal logic, yet are inherently intertwined.

(con't)

- High costs of R&D.
  - Related to the need to organize complex and expensive research processes, often with expensive research facilities.
- Interdisciplinarity - and hence the firm needs to combine a multitude of competencies and technologies.

APPROPRIATION (SF2)

- Appropriation not always evident. May require:
  - New combinations of knowledge fields
  - New combination with industrial knowledge
  - Organisational changes;
  - Market learning, etc.
- New knowledge & value can be created in both mature and emerging service and goods products (sectors).

(con't)

- Firms have differing abilities to appropriate economic value from new knowledge.

- Debates whether economic benefits are global or regional
  - Global (mobility, diffusion, product markets)
  - Regional (spill-over, institutions, unique individuals).

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ACTORS & NETWORKS (SF3)

- A multitude of diverse actors are involved, where they compete as well as interact in an intricate web of relations.
- Inter-organizational collaboration between private and public actors matter.

(con't)

- The firm as an organisational form is crucial to assemble the capabilities needed for exploiting knowledge within biotech.
- To some extent science-driven, scientists, universities and industrial R&D labs are key actors.
- User inputs appear to be crucial to innovations successful in the marketplace.

GOVERNMENT REGULATION (SF 4)

- Extensive regulatory issues.
  - The necessity and speed of regulation is often spurred by the rapid technological progress and the sensitive nature of applications.
- Perceptions, public debate, institutions and regulations strongly influence the actors' possibilities to appropriate innovation opportunities.
- Impacts vary over regions and nations.

So, types of research questions raised include:

- What is the division of labour between universities/public organizations and firms in the development of new knowledge?
- How and why does this change over time?
- How to explain change in strategy and change in environmental conditions/incentives?
- Why are these ’search processes’ organized in different ways in different industries/technologies?
- How to explain the economic value of certain types of knowledge?