

**AIM 2019 – Madrid – September 5<sup>th</sup> -8<sup>th</sup> .**

**Professor Jim Browne PhD, DSc, C.Eng.**

**President Emeritus, National University of Ireland Galway.**

**Member Royal Irish Academy.**

**Member Irish Academy of Engineering.**

AIM 2019 – Madrid – September 5th -8th .

Manufacturing in the 21<sup>st</sup> Century  
Challenges and Opportunities.

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

5. Digital Manufacturing

6. Beyond Industry 4.0

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

5. Digital Manufacturing

6. Beyond Industry 4.0

# New Economic Environment Industry 4.0

1<sup>st</sup> 1760s: Steam and Water Power, Mechanisation

2<sup>nd</sup> 1880s: Electricity, Division of Labour, Assembly Lines

3<sup>rd</sup> 1980s: Electronics, Computing, Flexible Automation.

4<sup>th</sup> 2010s: Cyber- Physical, Fusion of Physical and Digital Worlds - Industry 4.0

# Features of Industry 4.0

1. Built on the infrastructure of 3<sup>rd</sup> Industrial Revolution

1. Very High Speed of Change, but 'predictable'?

2. Impact on Individual, Economy and Society

3. Impact is ubiquitous; All Industries, Services, Health, Education, Personal Lives

4. Business and Industry: **Mass Customisation, Circular Manufacturing and Personalisation of Products and Services** achieved using **Disruptive Technologies**.



**Human Talent is a more important 'factor of production' than capital?**

**Data is a major resource.**

# Industry 4.0

Combines the strengths of traditional industries with internet and data technologies.

**Enables the production of 'SMART' products in integrated physical and information processes.**

Changes supply chains, business models and business processes.

Enables the availability of Smart Products.



**Industry 4.0 implies the integration of multiple technologies that impact products, production processes and business processes.**

# Disruptive Technologies

Robotics, Automation , Mobile Technologies, 3D Printing, Smart Materials etc.

Predictive Analytics, Data Analytics.

Sensor Technology, Automated Identification , Drones.

Internet of Things.

Cloud Computing and Storage, 'Blockchain' Technology.



# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

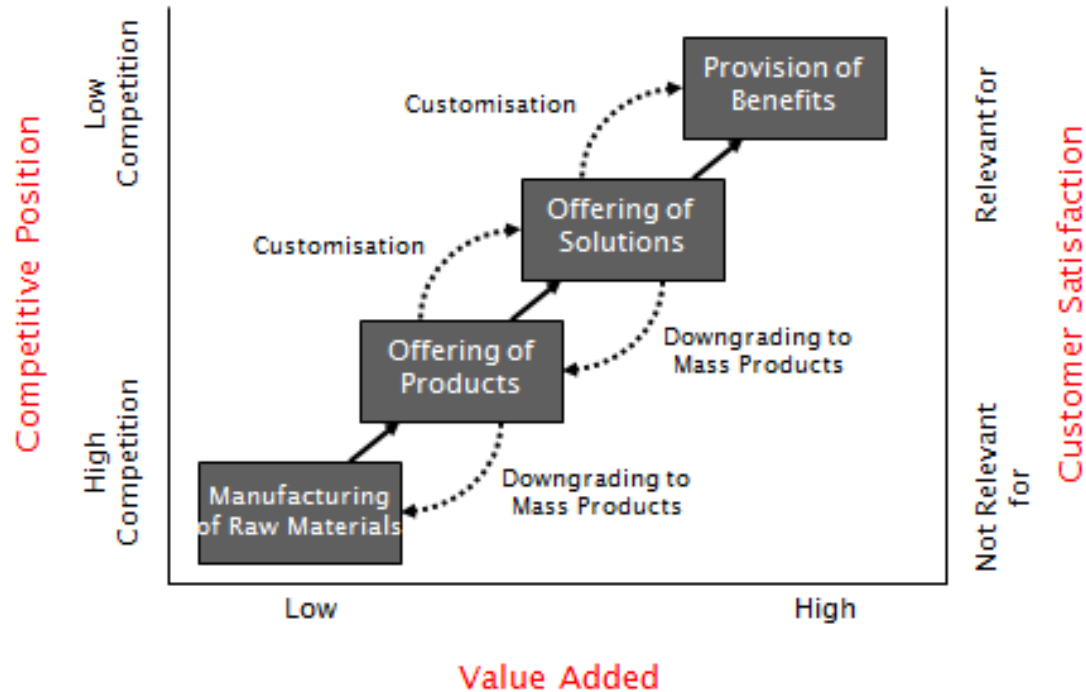
4. Circular Manufacturing – Clean Production.

5. Digital Manufacturing

6. Beyond Industry 4.0

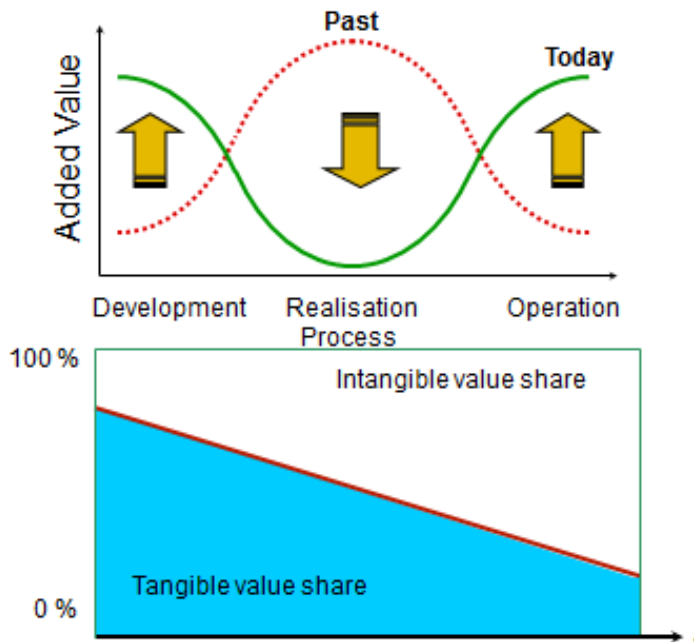
# Competitive Advantage.

## The Progress of Competitive Advantage



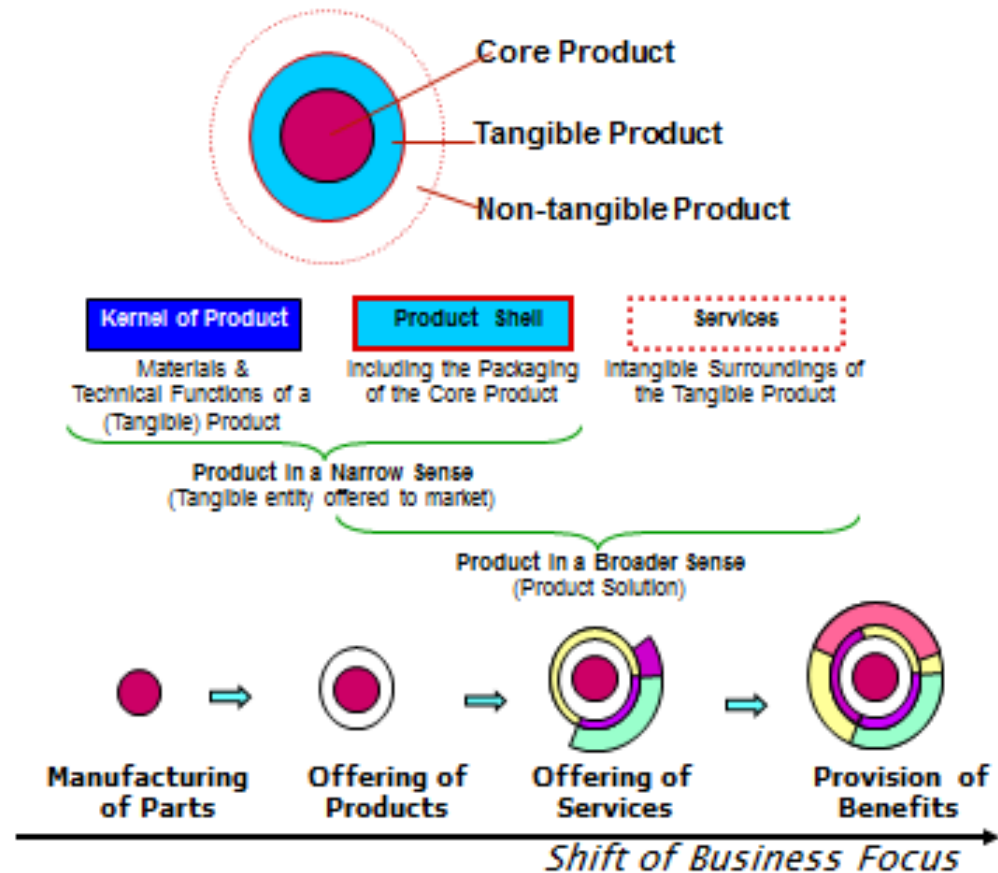
# Added Value in Products.

## *Added Value in Product Life Cycles*



# The Nature of Products.

## What is a Product?



# Smart Products.

Capable of executing computations, storing data, interacting with the environment and communicating.

Capable of identifying themselves and describing their properties, status and history.

Early implementation based on RFID, now incorporate full sensing, computing and communicating capability.

Capacity to support service, maintenance, interaction with the environment and 'end of life'.

# Product ID related questions

**In general, a smart product should be able to answer questions like:**

- Who are you?
- Who created you?
- Who owns you now?
- What kind of a product are you?
- Do you contain hazardous materials?
- Who repaired you?
- What has been happening to you?
- When are you going to expire?
- Where are you going?
- What is your destination?
- When should you arrive at your destination?
- Are you on the right route?
- Are you going in the right direction?
- Etc.

# More Product ID related questions

 **Products, or product components must be able to communicate their relationships to other "things".**

 **This enables a smart product to answer questions like:**

- To which order do you belong?
- To what shipment do you belong?
- To what sub-assembly do you belong?
- What service procedure was carried out on you?
- Etc.

# Product information available anywhere at any time

- **Product-centric information management:**

- ✓ Concentrating information around product instead of around companies
- ✓ Enables information sharing, easier access and management of the data
- ✓ Product information updates performed in real-time
- ✓ Product life cycle management becomes easier

- **Implemented by agent-based systems:**

- ✓ Internet-accessible software components
- ✓ Capable of handling information in "intelligent" ways
- ✓ Allows direct use of existing "best-practice" data management solutions from object-oriented programming



# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

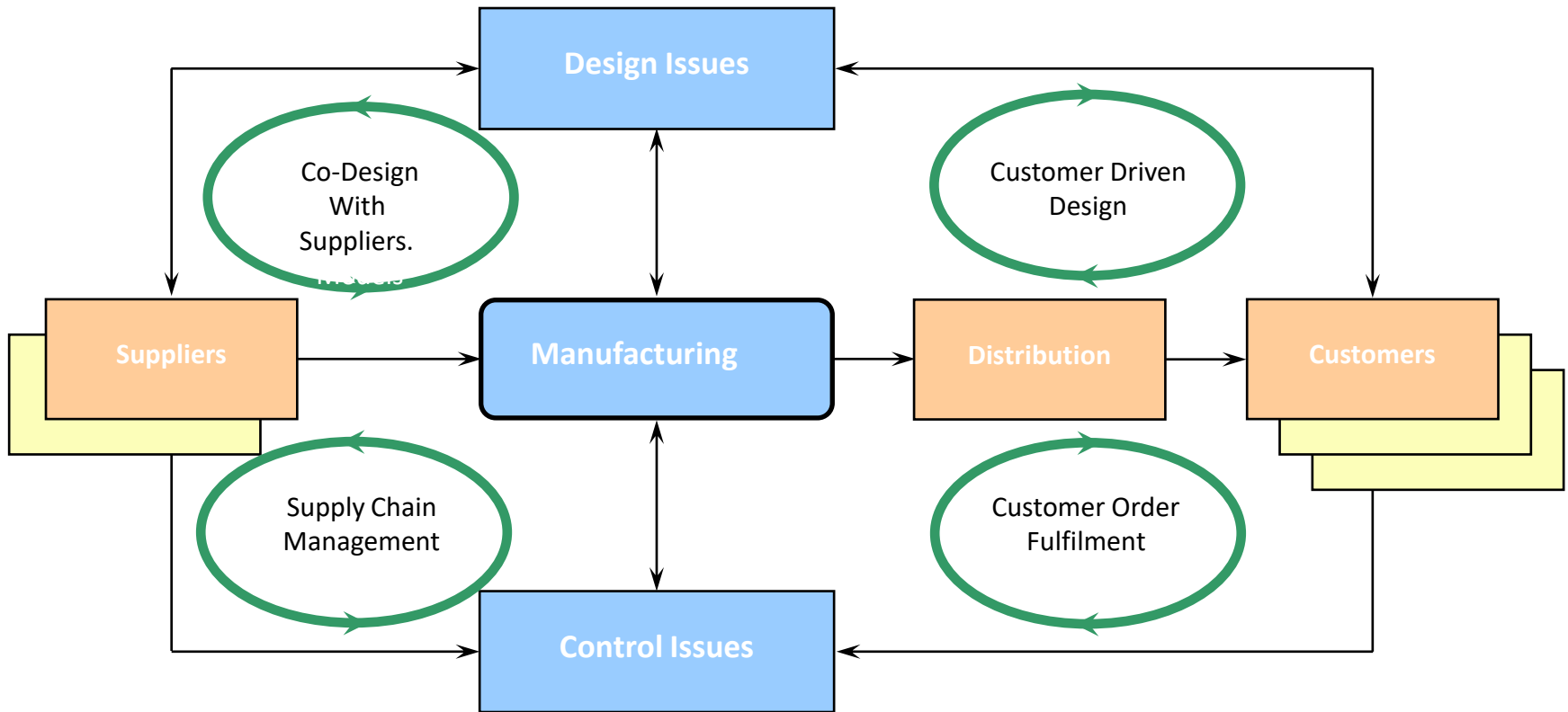
3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

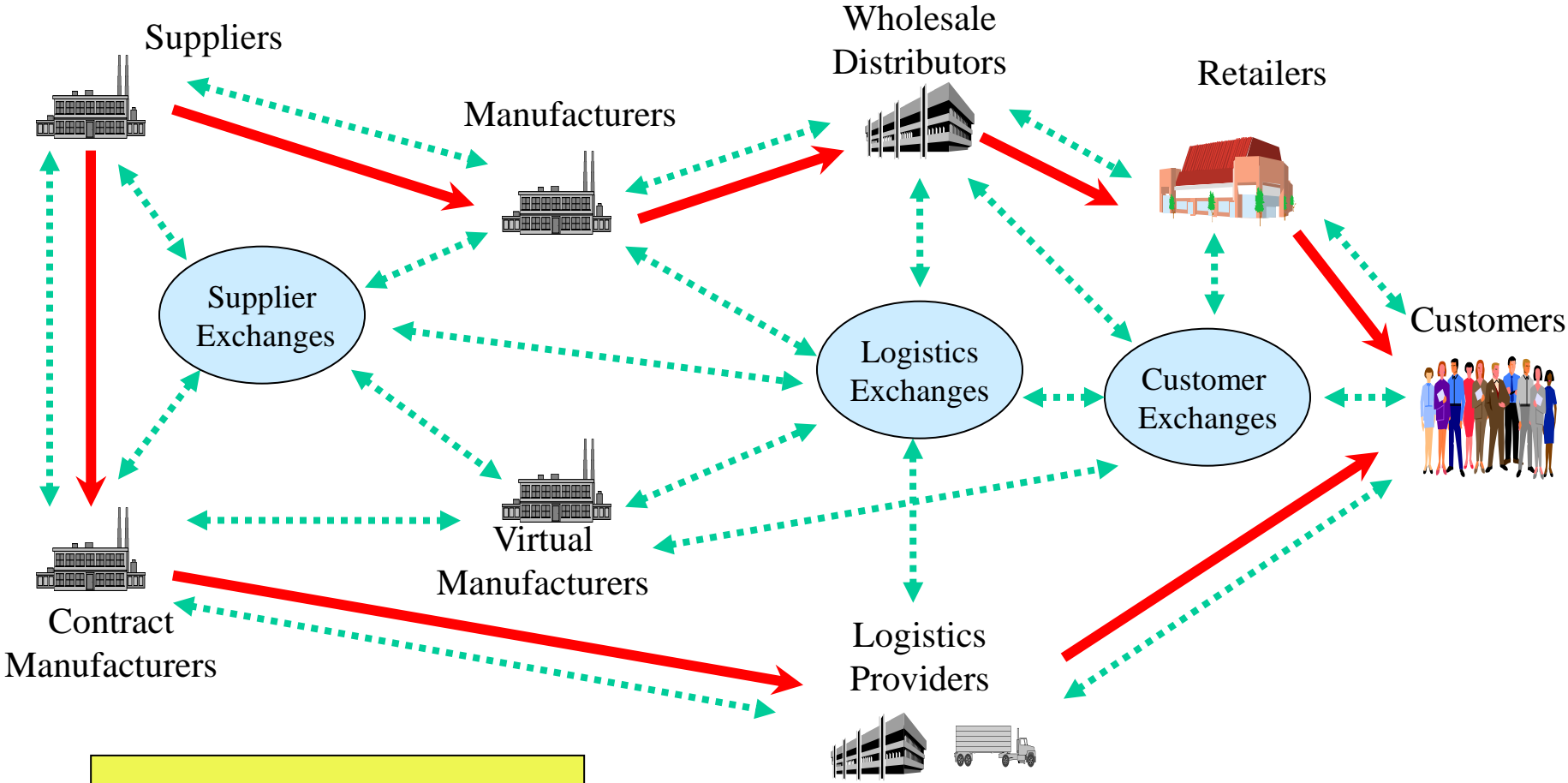
5. Digital Manufacturing

6. Beyond Industry 4.0

# Conventional Simplified Business Model



# Complex Supply Networks.

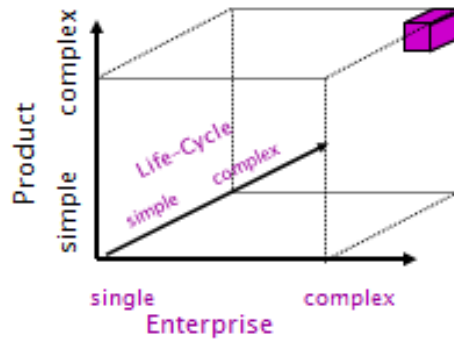


Information Flows  
Goods Flow

2/25/2020

26 August 2019

# Complex Products and 'Enterprises'.



Increase in variety of product features, including services.

- New / Extended Product Features
- Product related Services
- Customisation of Products (Mass Customisation)
- .....

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

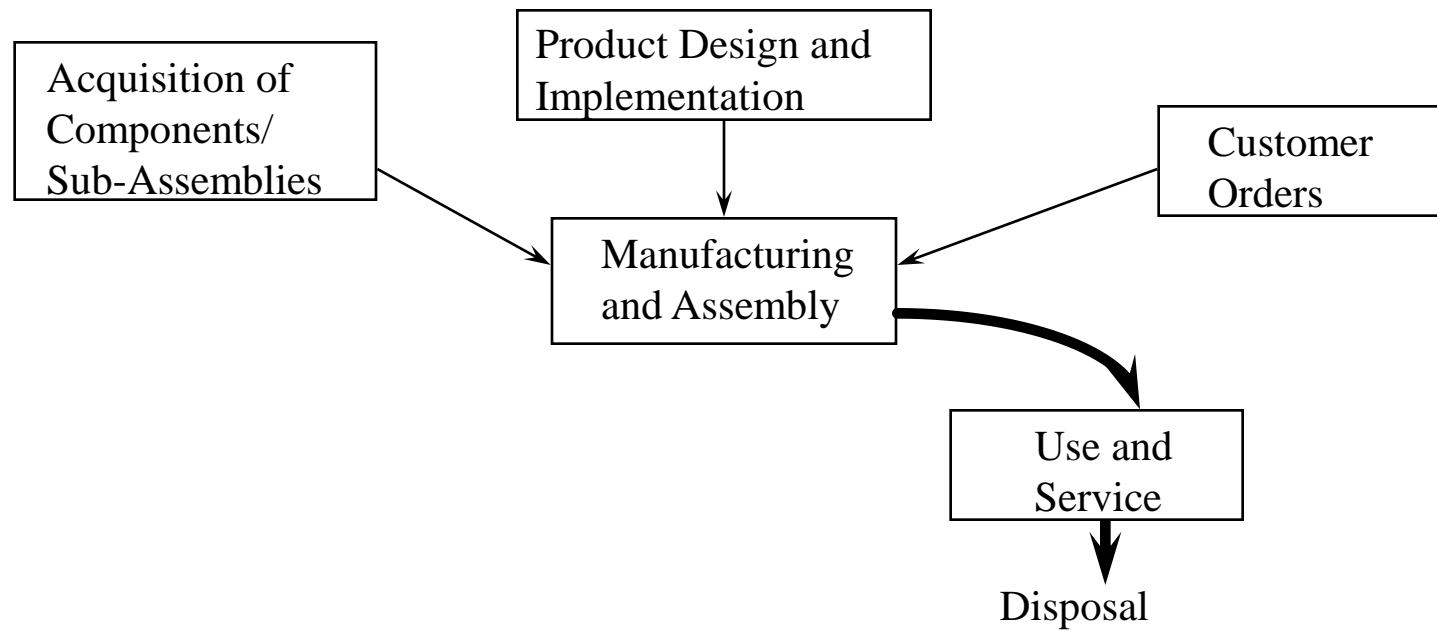
3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

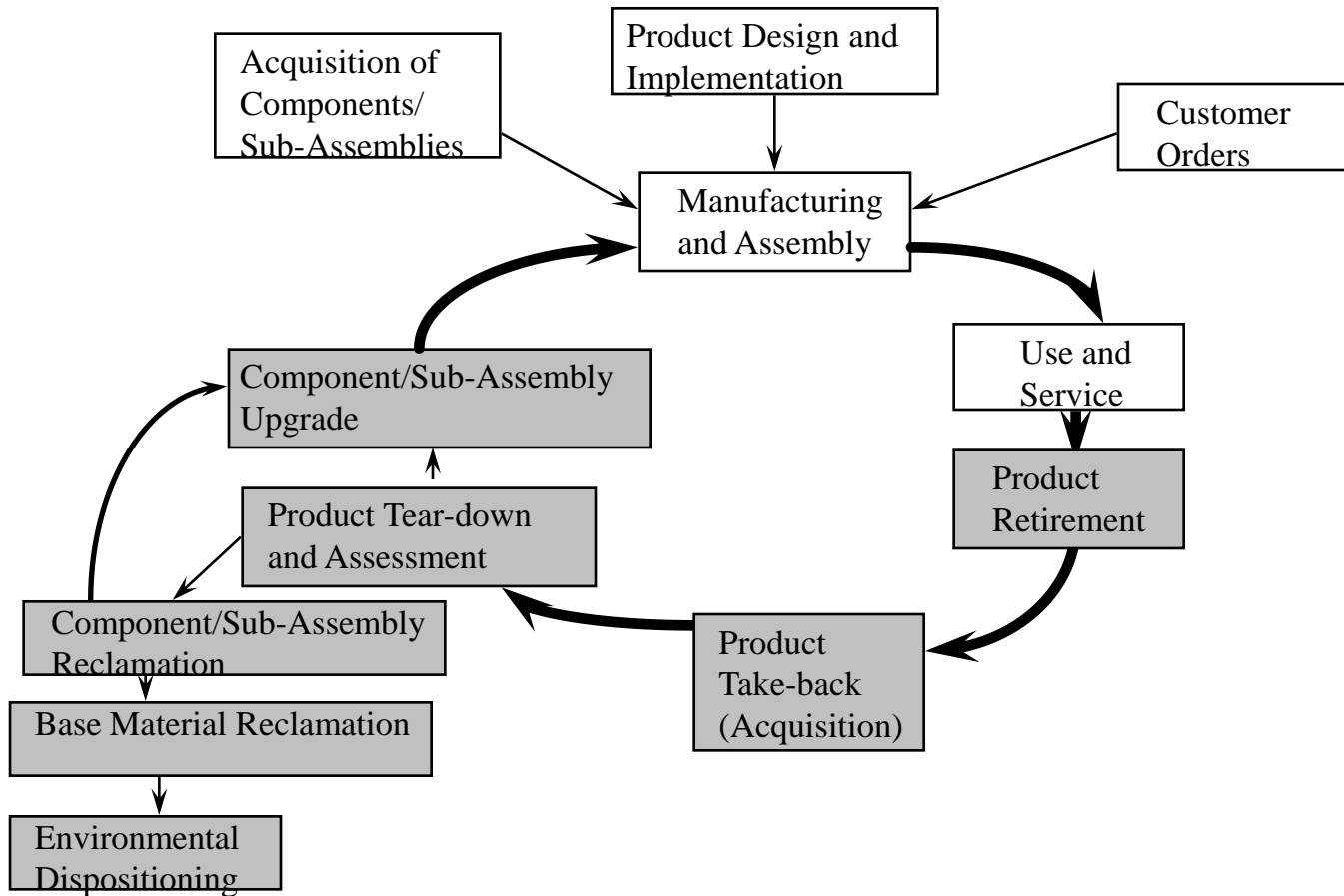
5. Digital Manufacturing

6. Beyond Industry 4.0

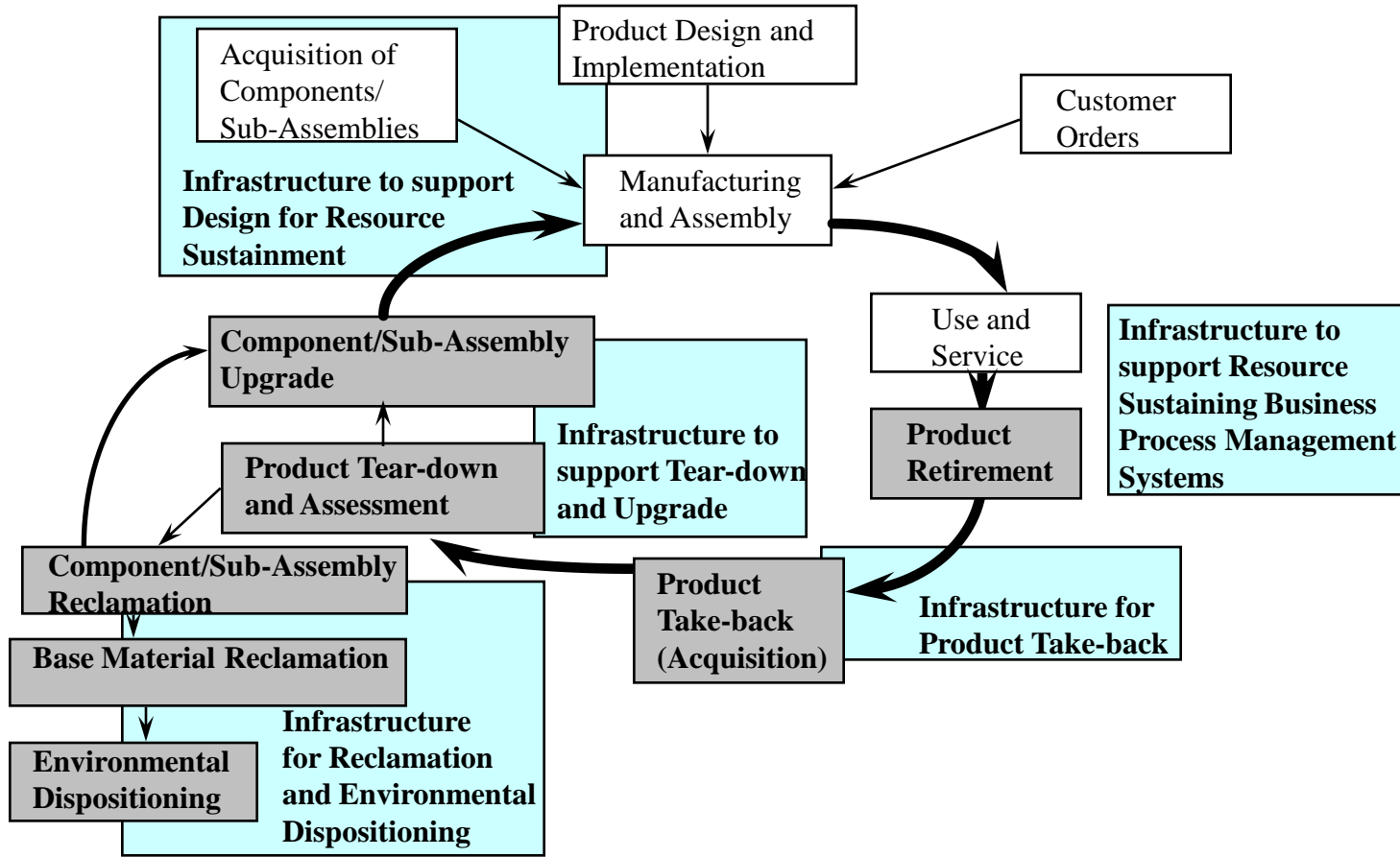
# Traditional Manufacturing Business Model.



# Circular Manufacturing - Resource Sustainment Business Model.



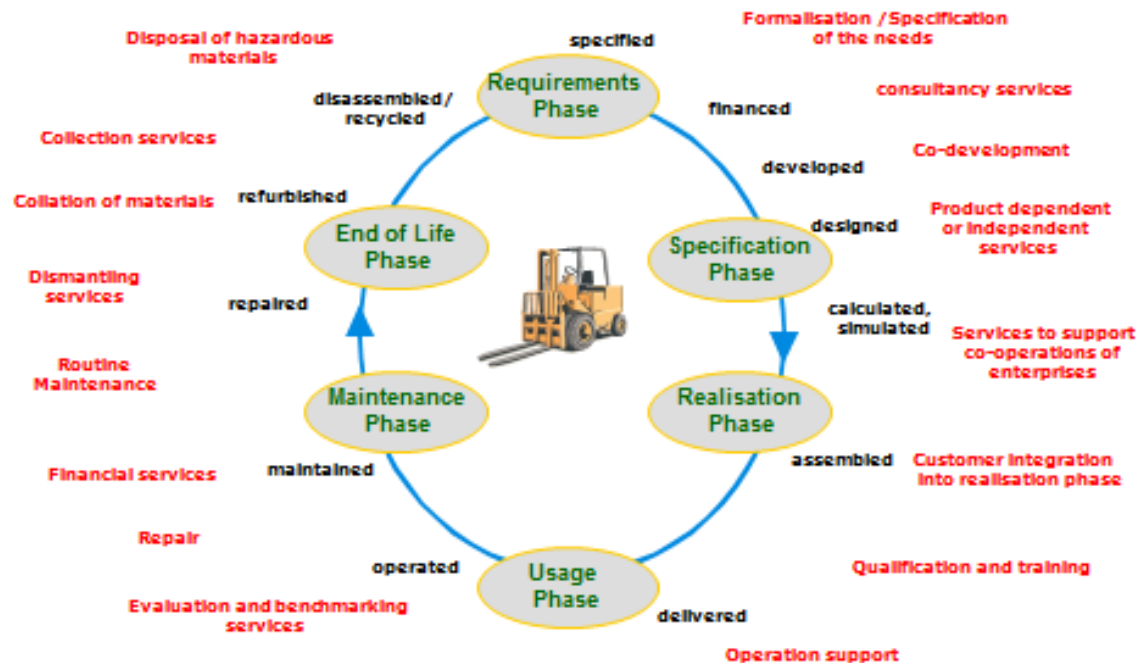
# Circular Manufacturing - Resource Sustainment Business Model.



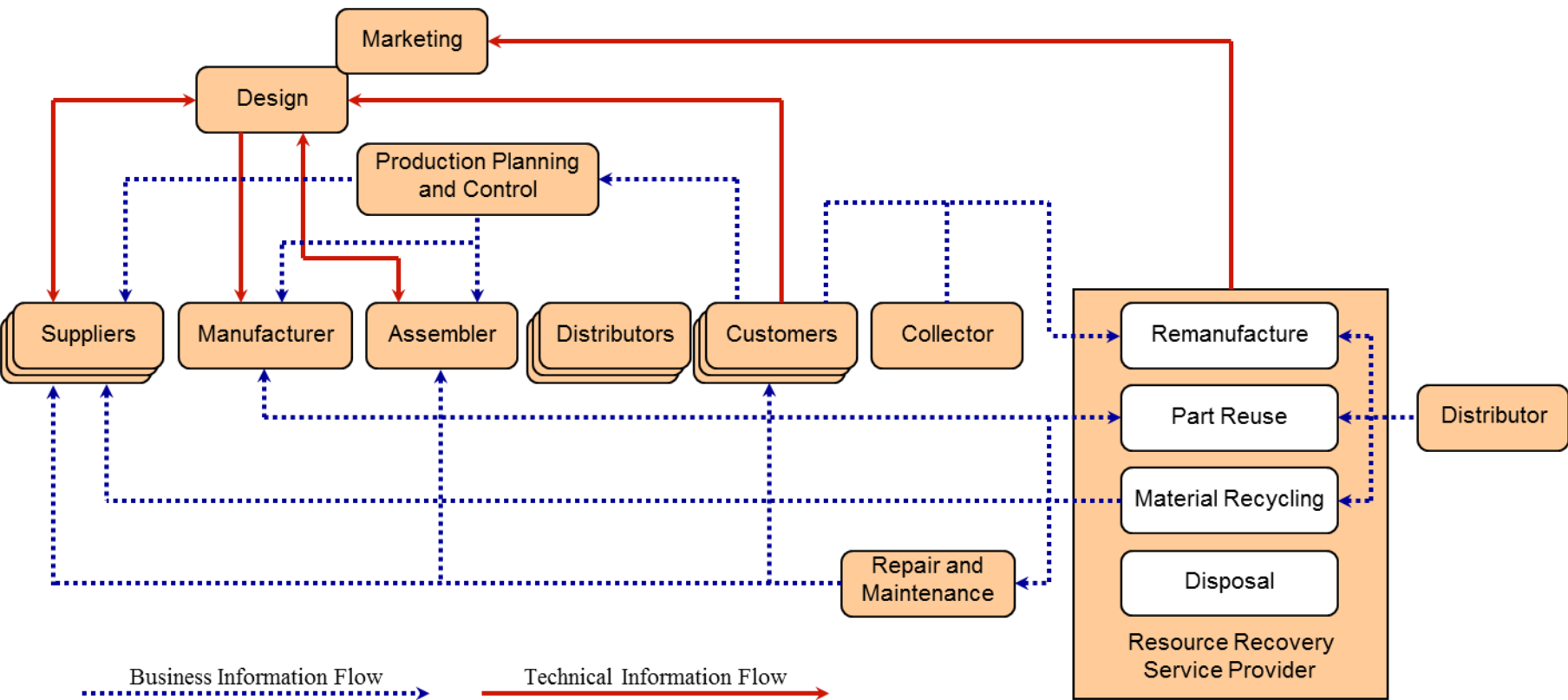


# The Complete Product Life Cycle.

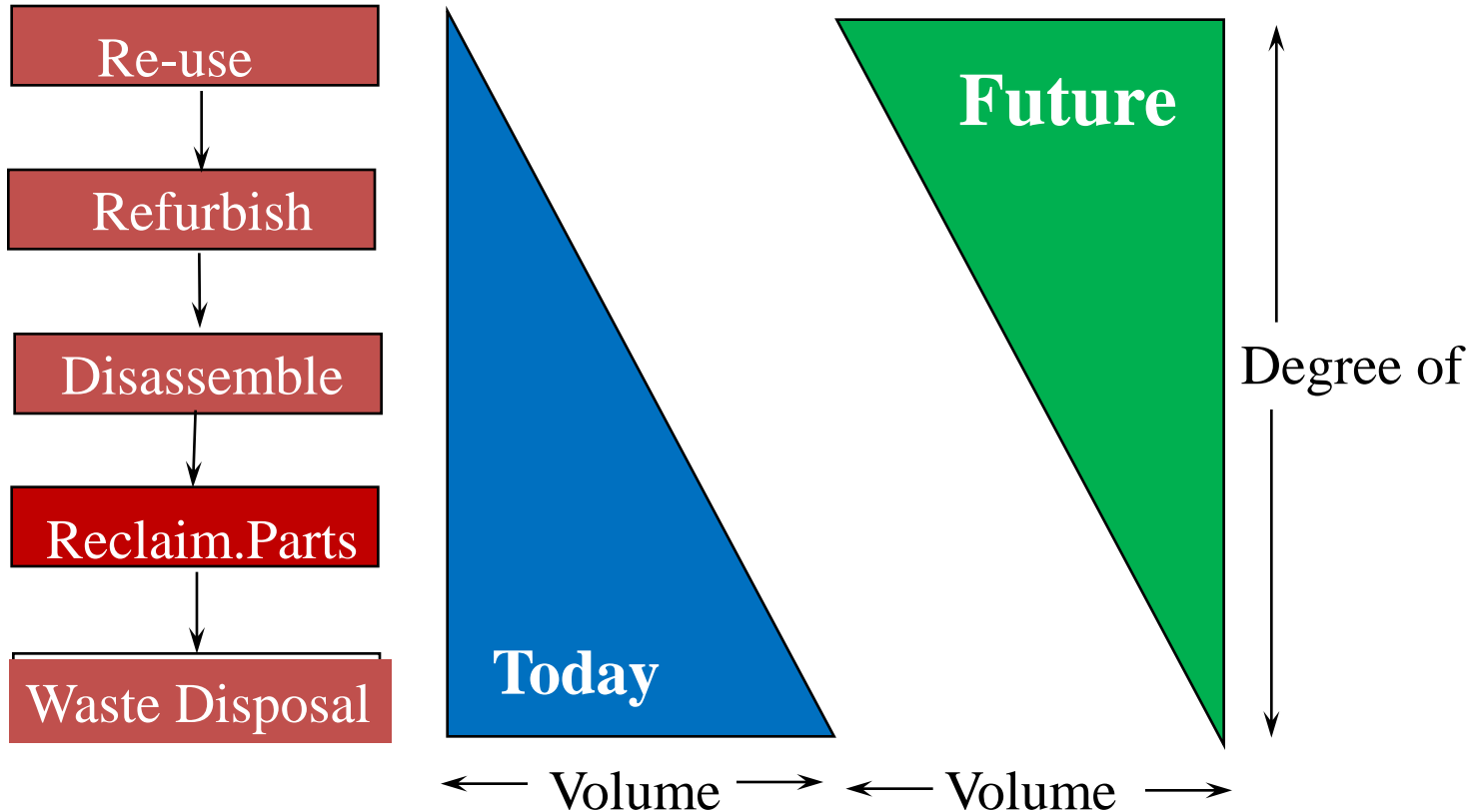
## Products & Services Along the Life-Cycle



# Business Model- Circular Manufacturing.



# Resource Recovery Model and Degree of Re-usability.



## Challenges - Circular Manufacturing.

### Key Issues:

- Product Design for Product Recovery.
- Customised Products and Product Recovery – Smart Products?
- Process Design for Clean Manufacturing.
- New Smart Materials – incl. replacement for scarce materials.
- Understand and redevelop business models.
- ‘Intelligent’ or Smart Products through sensors and IoT.
- New models of customer behaviour and customer expectations.

# Perspectives of Producers & Customers

**Buyer / Customer:**

**“Owner or User”?**



**Seller / Producer:**

**“Providing a product or the usage of a product”?**

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

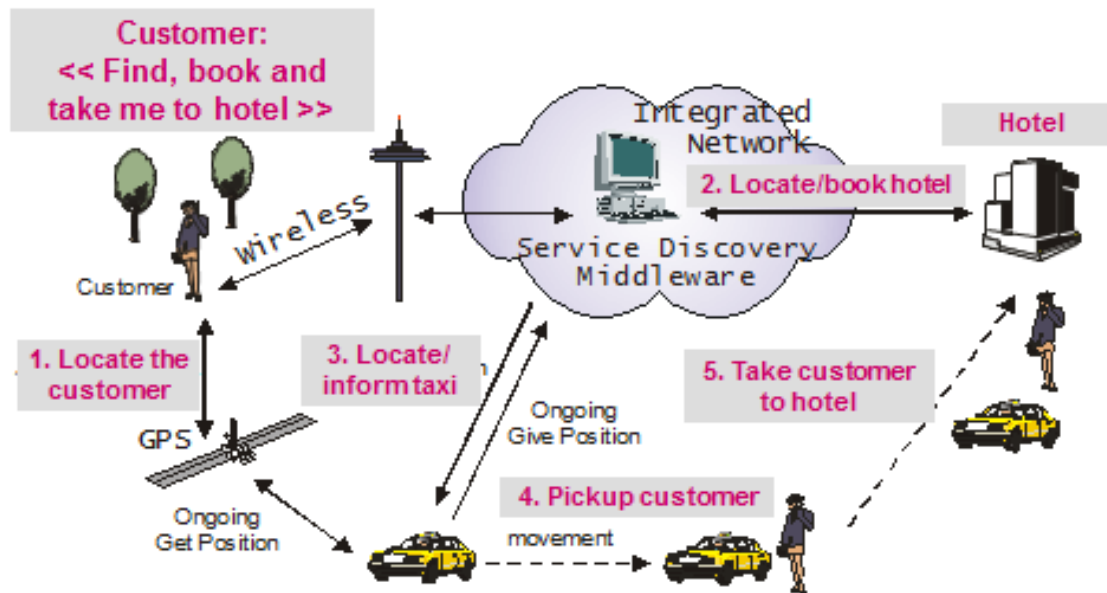
5. Digital Manufacturing

6. Beyond Industry 4.0

# Industry 4.0 and the Digitization of Manufacturing.

- Industry 4.0 implies two layers of business process integration:
  - ‘End to end’ across the value chain: customer through to supply.
  - Across the life cycle across the product: ‘Smart Products’.
- Implications:
  - Business process led and technology enabled.
  - Create a virtual copy of business value chain.
  - Create a ‘Digital Twin’ of the ‘Smart Product’.

# Today's Web Services - Tomorrow's Manufacturing. The 'Just in Time' Customer.





# Industry 4.0 – Future Manufacturing.

## GOAL:

- Ubiquitous, context and location independent collaborative digital business ...

## Analogy:

- The banking (cash and credit) model fully realised in the world of products and associated services.

## This means:

- Automated and “intelligent” machine to machine integration
- Integration of information and material flow
- Integration of information and human knowledge

## Keys:

- Standardisation of Processes
- Semantic web/ontology work crucial to integration of the information flow
- Material and information flow in:
  - Products and Built-In Services.
  - Collaborative business.

# Challenges- Digital Manufacturing.

- Collaborative business models and applications.
- Ubiquitous, context and location independent data.
- Profiling of enterprises and user markets.
- Harmonisation and standardisation issues.
- Harmonised legal framework for transactions.
- Automated and intelligent “machine to machine” integration.
- Semantic web and the definition of an ontology for digital business.

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

5. Digital Manufacturing

**6. Beyond Industry 4.0**

# Biologicalisation in Manufacturing.

## Definition.

‘The use and integration of biological and bio-inspired principles, materials, functions, structures and resources for intelligent and sustainable manufacturing technologies and systems with the aim of achieving their full potential.’ (CIRP, 2018.)

# Biologicalisation in Manufacturing.

“The big challenges of the 21st century ...global warming, access to freshwater, sustainable production of food and materials, and improving quality of life in ageing societies, require a new approach to science and engineering more closely coupled with nature.

Biologically inspired designs offer technologically novel and sustainable solutions ... not ... provided as quickly or economically by traditional approaches.

A deeper understanding of how biological systems work brings new insights .... to energy generation, conversion, storage, transport, and efficiency ... inspires advances in healthcare, introduces new age of materials with novel properties such as self-repair.” (European Science Foundation 2012.)

# Biologicalisation in Manufacturing.

“The big challenges of the 21st century ...global warming, access to freshwater, sustainable production of food and materials, and improving quality of life in ageing societies, require a new approach to science and engineering more closely coupled with nature.

Biologically inspired designs offer technologically novel and sustainable solutions ... not ... provided as quickly or economically by traditional approaches.

A deeper understanding of how biological systems work brings new insights .... to energy generation, conversion, storage, transport, and efficiency ... inspires advances in healthcare, introduces new age of materials with novel properties such as self-repair.” (European Science Foundation 2012.)

# Biologicalisation in Manufacturing - Today.

## New Products in Health Care and Biopharma.

1. Biologics.
2. Medical Devices; Hip Joints, Knee Joints, Stents including drug-eluting stents etc.
3. Personalised Medicine: stem cell based drugs.
4. Next generation cellular therapy products cellular immunotherapies, cancer vaccines, and other autologous and allogeneic cells for certain therapeutic applications.
5. Etc.

# Biologicalisation in Manufacturing.

**Manufacturing  
Materials**

**Health  
Food  
Agriculture**

**Environmental  
Sustainability  
Energy**



# Biology - Engineering

Products built from the 'bottom up' : **Additive Manufacturing.**

Life is cyclical and recycling is normal : **Circular Manufacturing.**

Biological Systems evolve and adapt : **Control Systems and Smart Products.**

Biological organisms co-exist and co-operate : **Supply Chains and Virtual Manufacturing Systems.**

# Structure of the Presentation

1. Evolution of Industry – Industry 4.0

2. The Nature of Products and Added Value.

3. The Nature of Enterprises - Virtual Chains / Networks.

4. Circular Manufacturing – Clean Production.

5. Digital Manufacturing

**6. Beyond Industry 4.0**