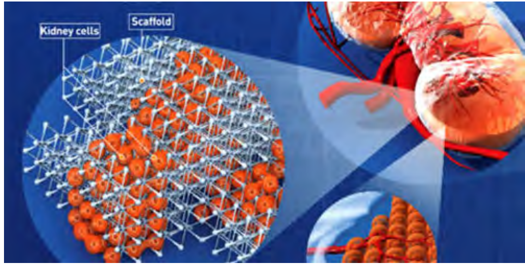


BIOFABRICATION FOR REGENERATIVE MEDICINE
FET FLAGSHIP 2016 JOINT PROPOSAL

Lorenzo Moroni

Heinz Riedl

Pier Maria Fornasari

Jose-Alain Sahel

Jos Malda

FET Flaghips – WP 2014-2015

European Commission
DG CONNECT
Dir C Excellence in Science

FET Flagships H2020

FET Flagships are ambitious, large-scale, long-term, science-driven, goal-oriented, roadmap-based research initiatives tackling grand challenges in S&T.

They are expected to:

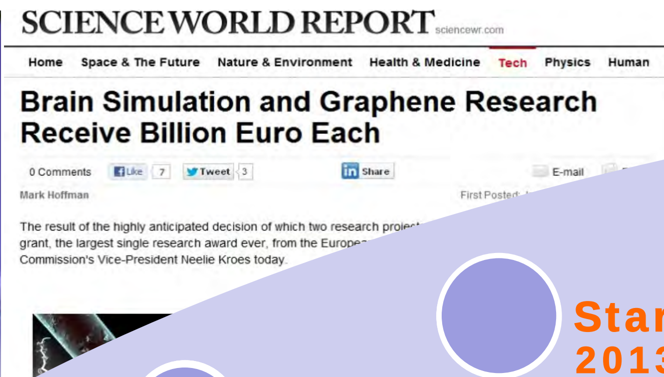
- provide S&T leadership, transformational impact on science, technology and society
- lead to novel innovation clusters in Europe
- facilitate alignment of national and regional research efforts, thus increase the impact of European research and innovation efforts

and will require:

- cooperation among a range of scientific communities/disciplines, with industries and with the involvement of representatives from the civil society
- a long-term commitment of all key stakeholders sharing a common scientific vision and under a strong leadership
- a joint effort of EU and national programmes to provide a large financial support (~ 100 M€/year over a long period: ~10 years)

European Commission

Graphene & Human Brain Project selected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Brain Simulation and Graphene Research Receive Billion Euro Each

0 Comments | Like 7 | Tweet 3 | Share | E-mail

Mark Hoffman

The result of the highly anticipated decision of which two research projec[...] grant, the largest single research award ever, from the Europe[...] Commission's Vice-President Neelie Kroes today.

Stimulating ideas & structuring the scientific community
2009 - 2010

Call for Preparatory Actions: 21 → 6
July 2010

Preparatory Phase Pilots
05/2011 - 04/2012

Flagship selection
6 → 2 winners
end 2012

Start
2013-10-01

FP7 ramp-up phase
10/2013- 03/2016

Starting with
80-85 partners per flagship

EC funding of **€ 54 millions** each
for 30 months

European Commission

Open consultation on FET Flagship for Horizon 2020 next Work Programme

Published on 10/02/2016

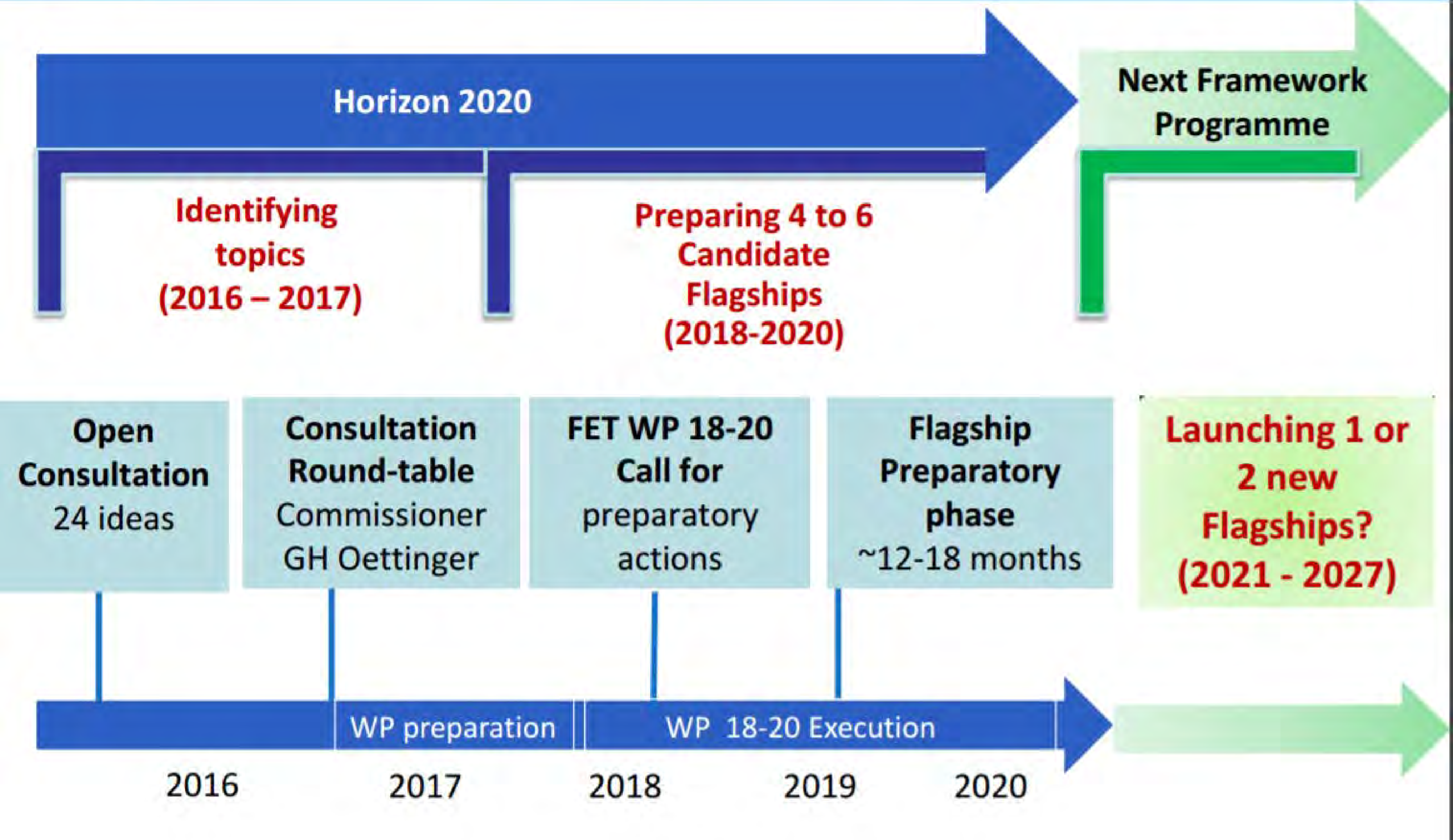
Do you have a great idea for a research theme that could lead to a new technology? Could it become real if Europe's best minds were put together to work on it? Share your view and the European Commission can make it happen via its Future and Emerging Technologies (FET) Flagship programme.

Date: From 10/02/2016 to 30/04/2016

Share

The aim of this consultation is to identify promising and potentially game-changing themes for future research in technological, multidisciplinary domains leading to innovations with important economic and societal benefits for Europe, in particular boosting investments for growth and jobs.
It takes place in the context of the preparation for the FET Work Programme for the period 2018-2020 of Horizon 2020, and concerns specifically the FET Flagship scheme. Another consultation dedicated to the FET Proactive scheme is also launched.

Timeline for new FET-Flagships

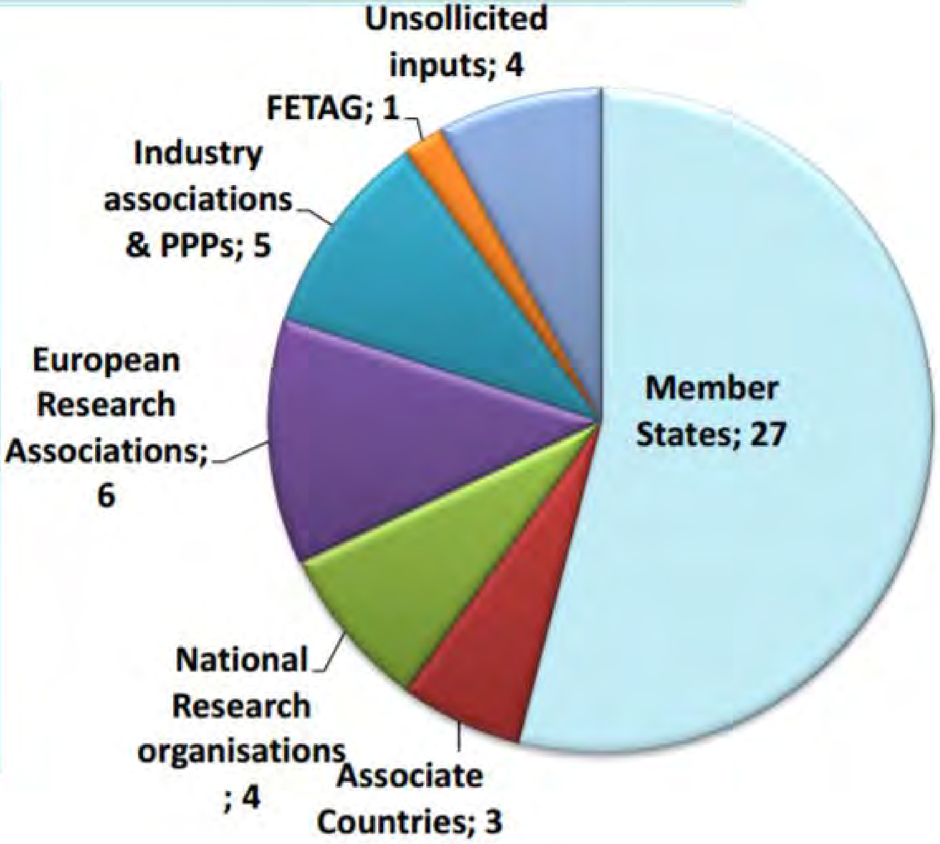


Round Table of 15 Dec 2016: Inputs

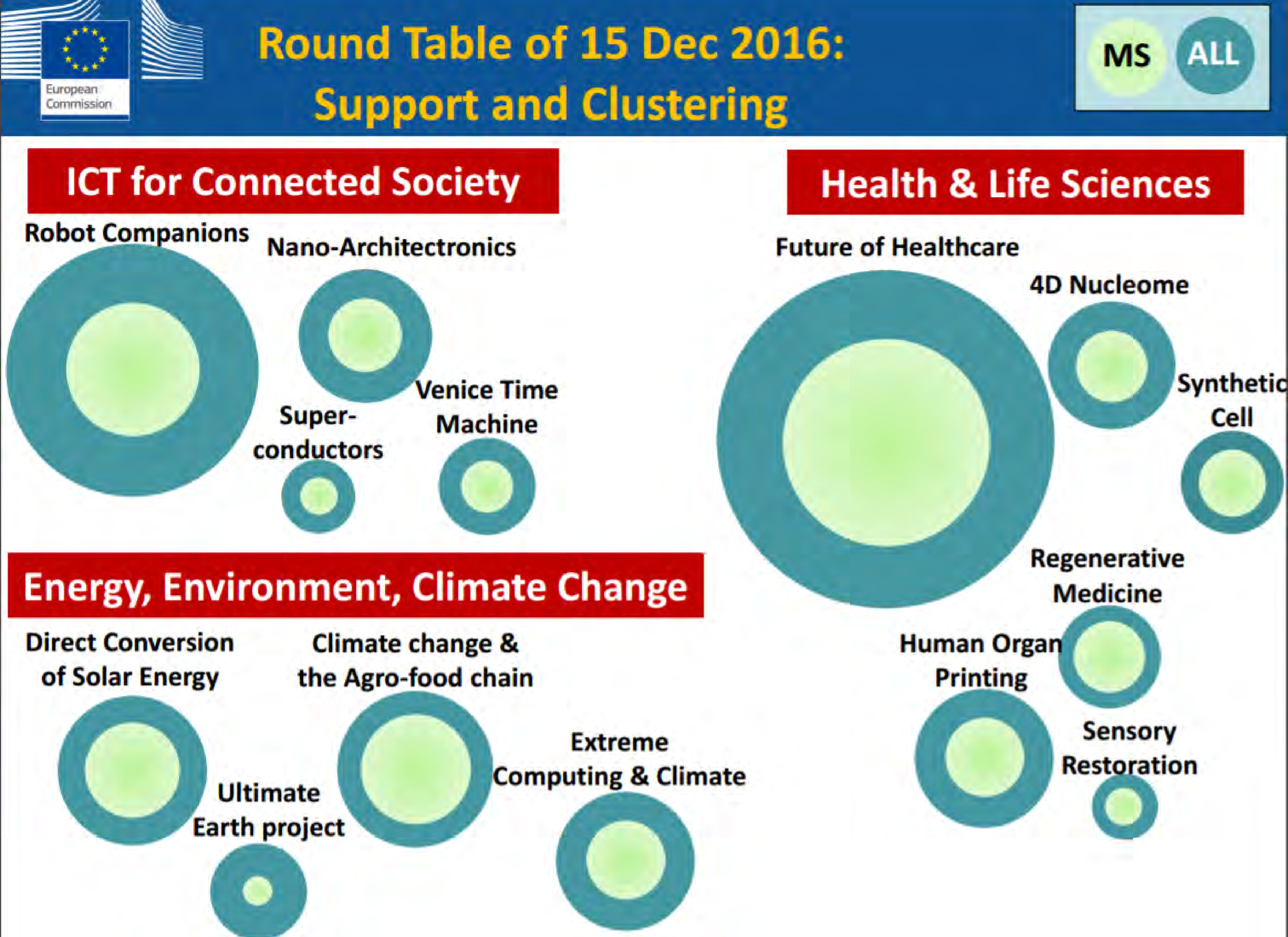
Participation by representatives from 27 MS and 3 AC, as well as 23 other organisations (research organisations, research associations, industry, ...)

50 position papers expressing:

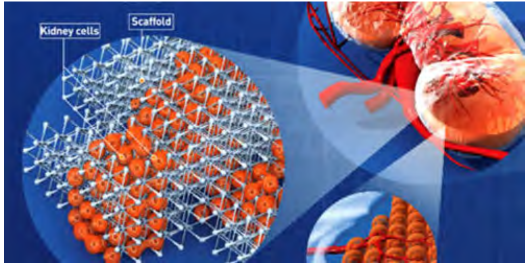
- support to 14/24 topics submitted at the public consultation
- views to merging several topics
- support to a few new topics
- ... but also the need to review implementation & governance, selection procedures, etc.



Round Table of 15 Dec 2016: Support and Clustering



Biofabrication for Regenerative Medicine



3 Fet Flagship proposals

- HOPE (Human Organ Printing Era),
- ERMI (European Regenerative Medicine Initiative),
- Sensory Restoration and

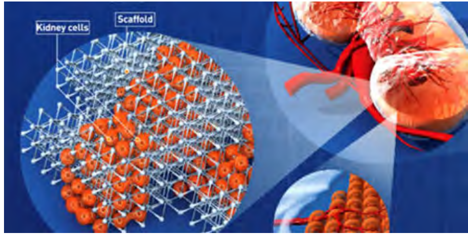
1 Fet Proactive proposal

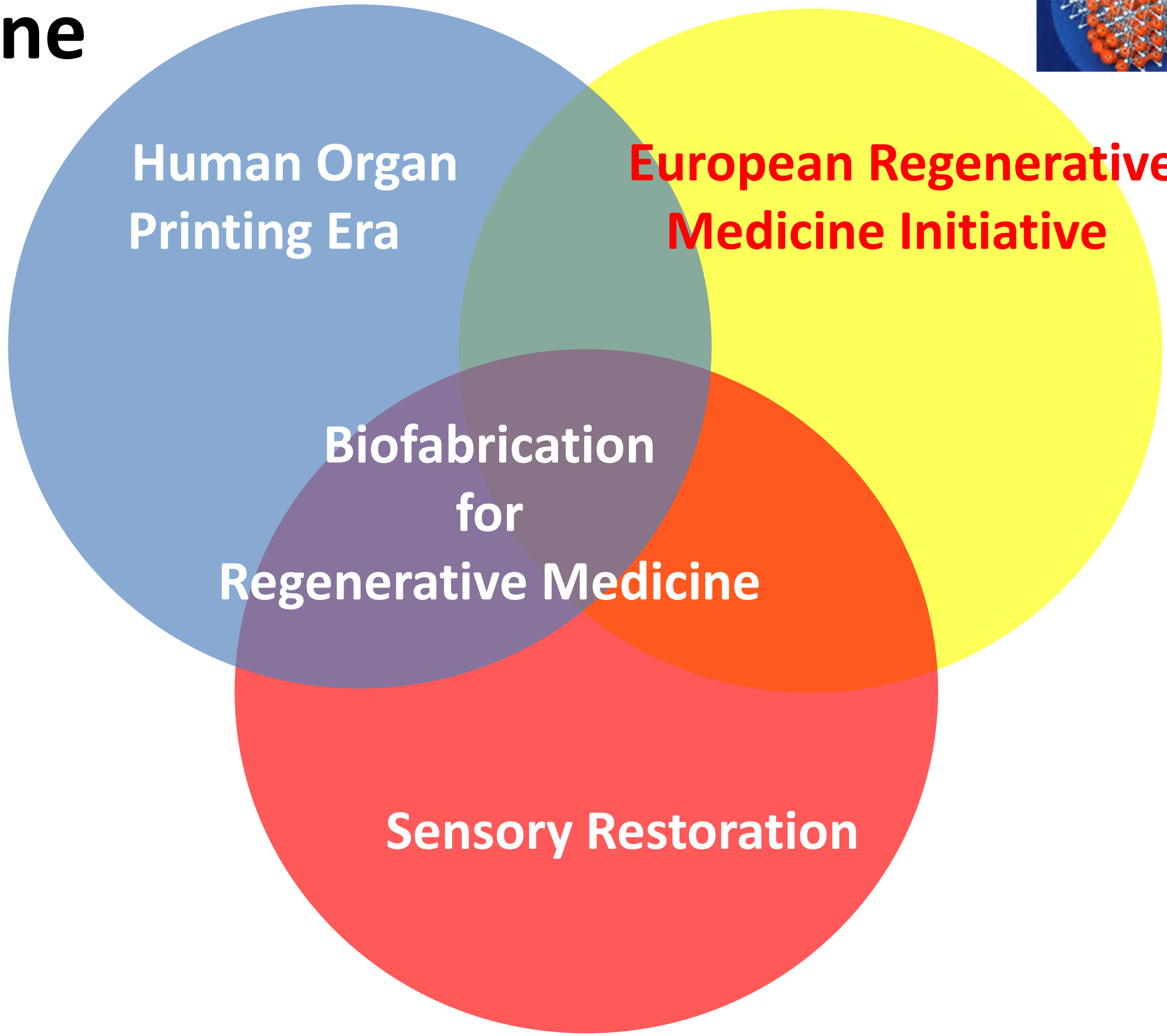
- Organ-on-a-chip

in October 2016 have decided to fuse into a new joined proposal named «**Biofabrication For Regenerative Medicine**», considering the enhanced possibilities given by the collaboration.

The new joint proposal has been officially communicated to European Commission offices (Dr. Thomas Skordas).

Biofabrication for Regenerative Medicine

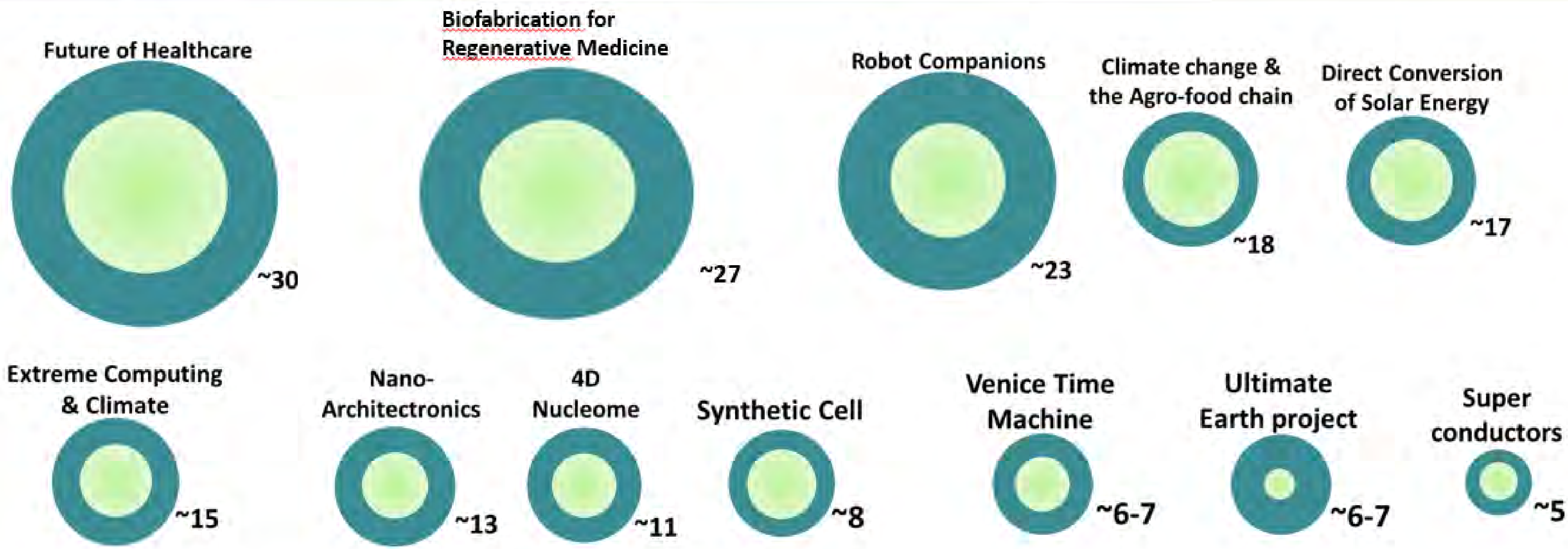




Fusion of Human Organ Printing, Regenerative Medicine, Sensory Restoration, Organ-on-Chip

European Commission

12 Ideas for Flagship



European Commission

European Commission

Round Table of 15 Dec 2016: Other ideas for Flagships

ICT for Connected Society

- Artificial Intelligence
- ICT for social sciences (understanding digital transformation of societies, evolving societies, etc.)

Health & Life Sciences

- Nano-medicine technologies
- Electroporation technologies

Other S&T Areas

- Materials science & nanomaterials
- A resilient and dynamic Europe in a globalised world

Energy, Environment, Climate Change

- Ocean space technologies

European Commission

Round Table of 15 Dec 2016: Main Conclusions

- Support for launching preparatory actions for new Flagships
- MS and Commission to jointly prepare new Flagships
- Consider recommendations from the FET Flagship high-level interim evaluation panel
- Three main areas: ICT and Connected Society; Health & Life Science; Energy, Environment and Climate Change
  - Most supported ideas from consultation/roundtable create the perimeter of call text per area
  - Open call with possibilities for new ideas, merging of ideas, etc.

Moving to the H2020 WP 2018-2020: Scope of Preparatory Actions

- Aim at developing:
  - **A consolidated vision** based on a well-defined unifying goal thoroughly justified in terms of S&T advances and of its targeted impact on economy and society
  - **A strategic research roadmap**
  - **A governance structure**
  - **Industry commitment and support**
  - **Approach to education and RRI (gender aspects, social and ethical aspects, legal implications, …)**
- Activities of Preparatory Actions:
  - **Consultations with research communities from different disciplines**
  - **Build Support by Stakeholders (including Industry)**
  - **Interaction with MS and national initiatives**
  - **Interaction with / outreach to citizens**
  - **Joint dissemination event**

Moving to the H2020 WP 2018-2020: Call Areas (DRAFT)

- ICT and Connected Society
- Health & Life Science
- Energy, Environment and Climate Change

- *Call open to all*
- *Proposals to cover one or more topic per area or parts of them*

Work Programme 2018-2020 Timeline

- Today: first discussion
- Spring: preparing the work programme text
- Autumn: validation by the FET programme committee
- Call soon after
- Duration of actions: 18 months

FETFLAG-01-2018: Preparatory Actions for new FET Flagships

This topic aims at launching coordination and support actions (CSA) to prepare new candidate FET Flagships.

Specific Challenge: FET Flagships are science- and technology-driven, large-scale, multidisciplinary research initiatives built around a visionary unifying goal. They tackle grand science and technology (S&T) challenges requiring cooperation among a range of disciplines, communities and programmes. FET Flagships should provide a strong and broad basis for future innovation and economic exploitation, as well as novel benefits for society of a potential high impact. The overarching nature and magnitude implies that they can only be realised through a collaborative long-term and sustained effort.

Scope: Proposals should contain a description of a potential FET Flagship and how this is to be matured over the course of the preparatory action into a more complete blueprint.

Firstly, proposals should describe the FET Flagship initiative they propose to further develop through this preparatory action, by specifically addressing the following three key issues:

- **What makes this a FET Flagship**: what is the unifying goal, the grand S&T challenge and the underlying vision; why is this a grand challenge and what makes it a "game-changer"; what are its main goals and objectives; and what are the technologies, including digital technologies, that it would advance;.
- **Impact (why it is good for Europe)**: will it bring major impact on science and technology; why is it relevant for the European industry; what is its innovation potential

that would benefit Europe's economy and/or society; how would it uniquely position Europe with respect to similar initiatives existing in other regions in the world.

- **Integration and European added value**: is it well positioned to address the grand S&T challenge in terms of large-scale integration of disciplines, academia and industry stakeholders; do critical mass in terms of research excellence and industrial capabilities exist in Europe that are needed to address the challenge; what is the estimated scale of the effort required to reach the objectives and how long will it take to do so; and, are there similar initiatives existing at regional, national or European level and what is the added value of such an effort.

Secondly, proposals should describe how the activities of the preparatory action will involve stakeholders over the course of up to 12 months (indicative), to arrive at a complete design and description of a candidate FET Flagship initiative. Specifically, they should describe the proposed activities for further developing the Flagship's unifying goal and its underlying S&T roadmap; attracting industry's endorsement and participation; further developing their consortium and its governance structure and attracting large public support.

Proposals should consider multidisciplinary aspects, including where relevant social sciences and humanities. They must also describe a clear strategy for dissemination and citizen engagement; and, in close cooperation with other proposals for preparatory actions that may be selected from this call, jointly organise and participate in an event addressing scientific communities, policy makers and the wider public and aiming at disseminating the main findings of the actions.

At the end of the action, the design and description of the candidate Flagship should include the following elements:

- **A consolidated vision** based on a well-defined unifying goal thoroughly justified in terms of S&T advances and of its targeted impact on economy and society
- **A strategic research roadmap**, showing how the unifying goal can be realised and what are the major milestones, situating the Flagship in the global landscape and demonstrating a credible path towards technology development, innovation and exploitation.
- **A blueprint for the Flagship's implementation** setting out the overall framework, and the identification of necessary competencies and resources including infrastructure aspects
- **A governance structure**, including the scientific leadership and the relations with Member States, with the Commission and with the relevant funding agencies.
- **Support from industry**, giving a view on avenues for exploitation and positioning of European industry in the global landscape
- **An approach to address responsible research and innovation**, in particular aspects such as education, gender aspects and societal, ethical and legal implications.

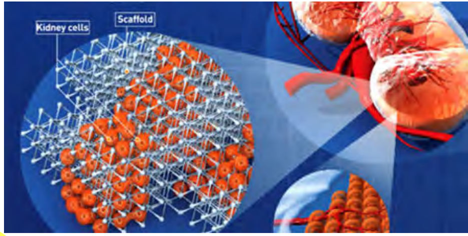
Proposals for candidate FET Flagship must address one of the following three main areas: **ICT and Connected Society**, **Health and Life Sciences**, or **Energy, Environment and**

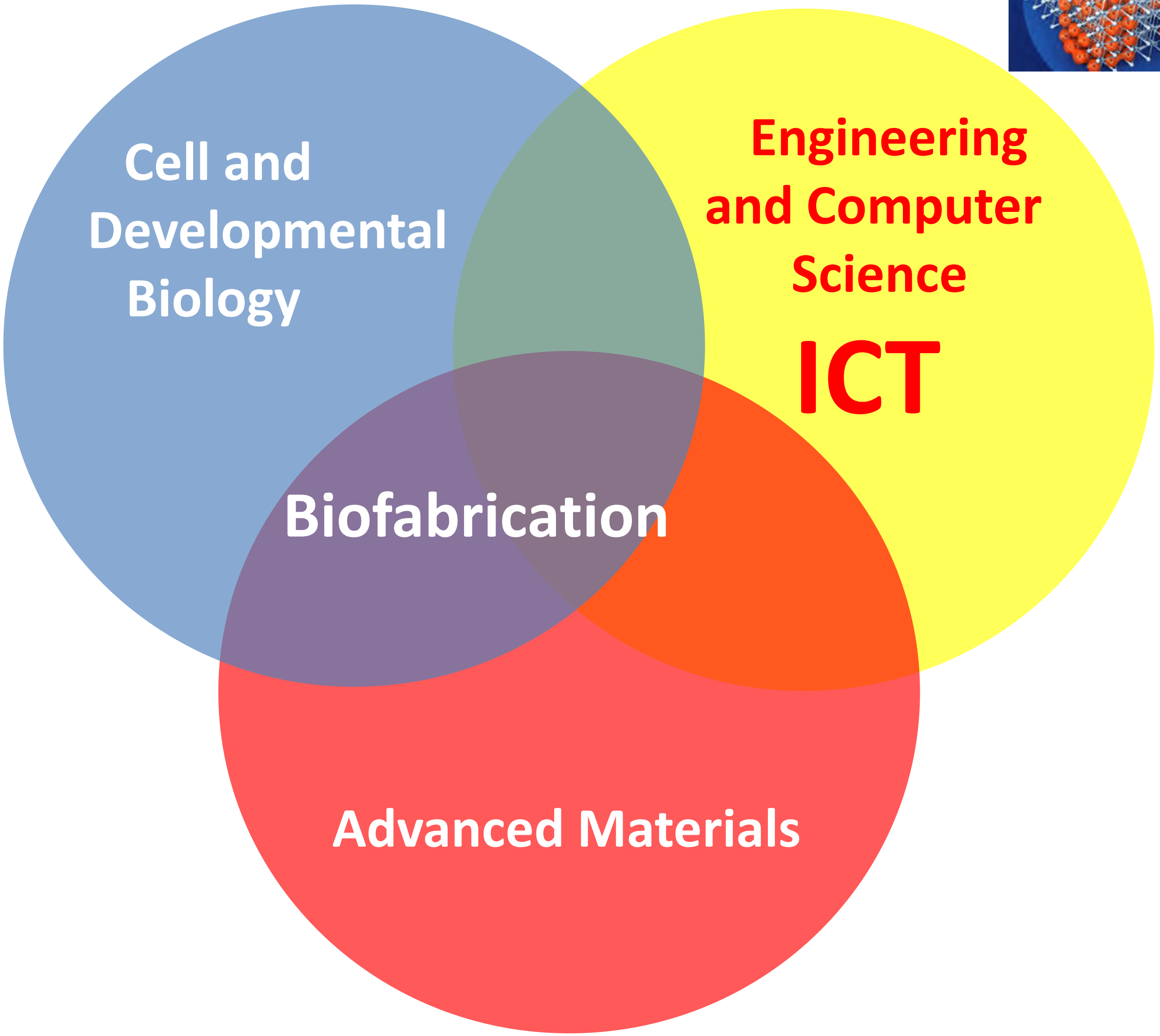
(2) Health and the Life Sciences

Proposals should address any of the following topics:

- **Disruptive ICT to Revolutionise Healthcare**: New technologies and approaches aiming at a paradigm shift to prevention and treatment of diseases. This includes in particular methods to use patients' genetic make-up to provide individualised prevention and treatment, nano-medicine approaches including novel uses of bio-sensors, organ-on-a-chip technologies, radically new technologies for drug development, precision medicine, regenerative medicine and biofabrication techniques to replace human cells, tissues and whole organs.
- **Understanding Life by Exploring the Genome and the Cell:** Novel technologies and approaches that enable a paradigm shift in studying and understanding the foundational building blocks of life, e.g., the functioning of the human cell and full genome/proteome/metabolome, opening up radically new opportunities in biology, advanced drug delivery and screening methods, and developing novel bio-nano-devices and technologies and advanced analytical and morphological technologies.

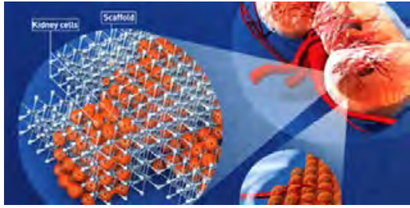
Biofabrication for R.M. is a Convergent Science





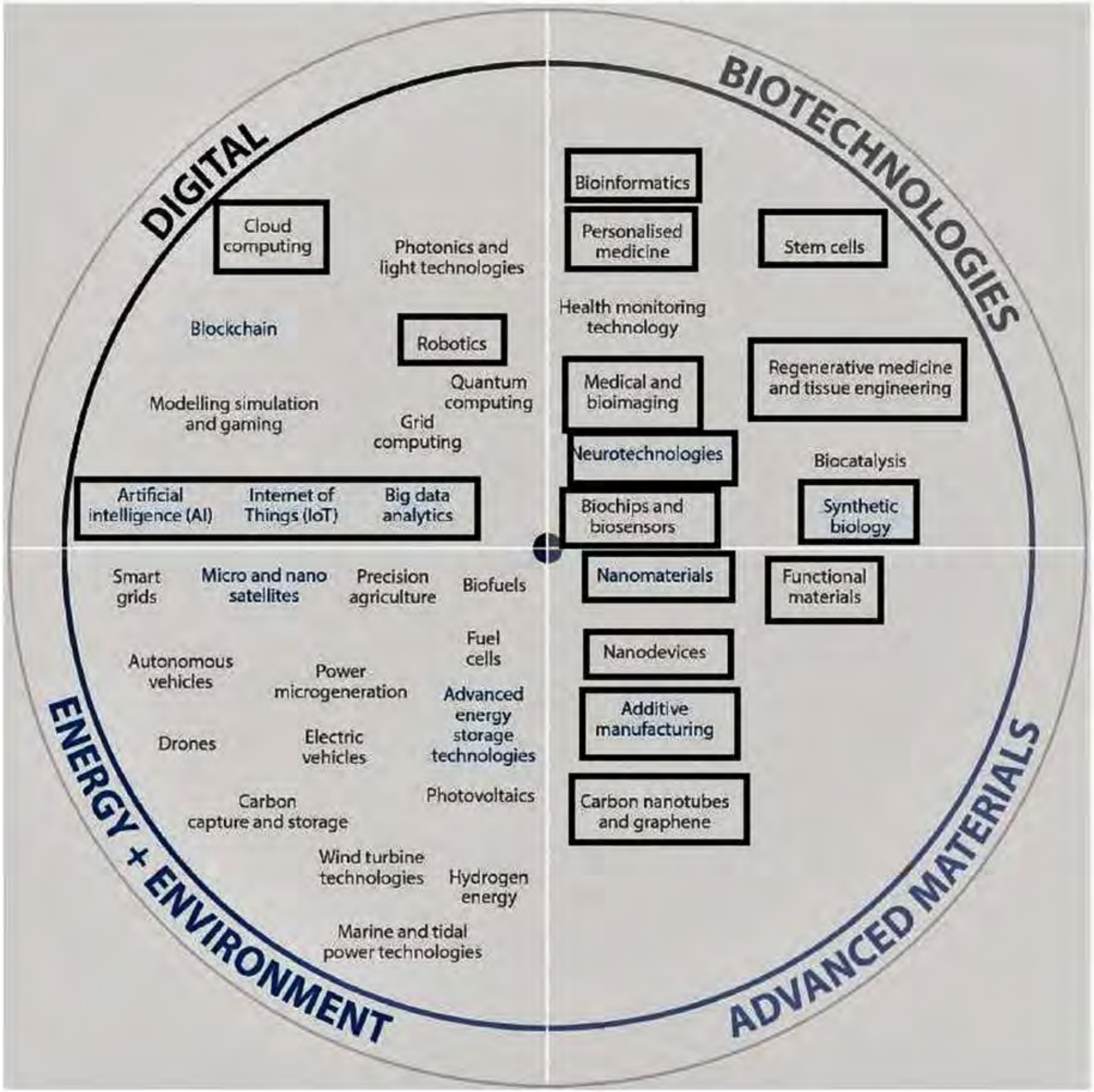
4.0 Biomedical Revolution: Emergence of Convergent Science

Biofabrication for Regenerative Medicine and the Digital revolution in Medicine 4.0

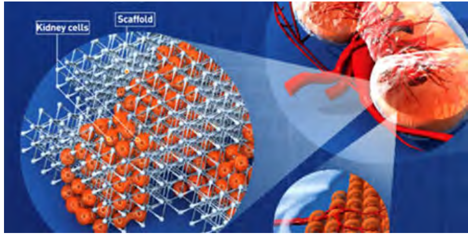


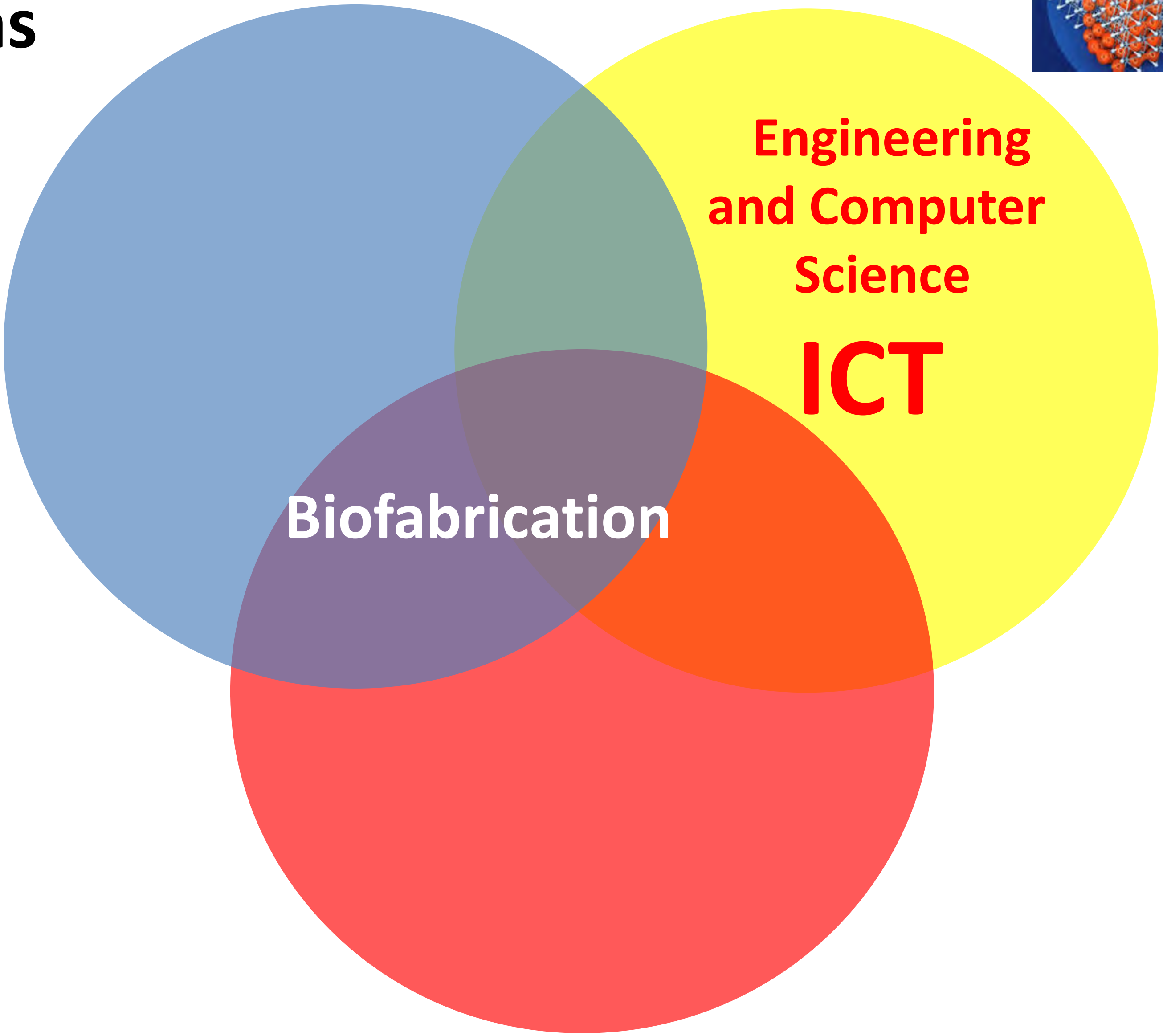
Biofabrication for Regenerative Medicine covers the 18 following fields in Digital, Biotechnology and Advanced Materials KET

40 key and emerging technologies for the future



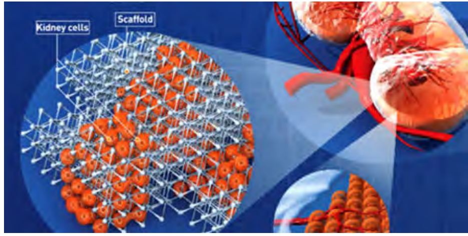
Biofabrication for R.M. covers Digital ICT areas





4.0 Biomedical Revolution: Emergence of Convergent Science

INFORMATION TECHNOLOGY AND HEALTHCARE

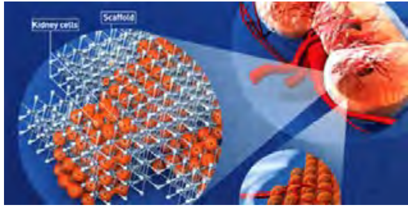


IT is a myriad of technologies for information processing, including software, hardware, communications technologies and related services, not including embedded technologies that do not generate data for use in general.

3D printing and bioprinting are defined as branches of IT.

IT has become an intrinsic part of the healthcare ecosystem in recent years

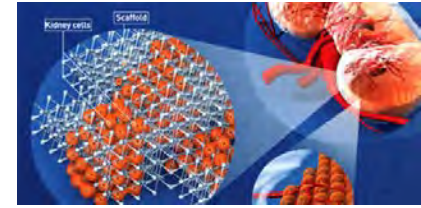
What is ICT role in Biofabrication for Regenerative Medicine



Biofabrication technology is evolving into a complex system composed of many processes, including computer-aided design (Bio-CAD), computer-aided engineering (BioCAE), computer-aided manufacturing (Bio-CAM) and biological processes, which depend on the combination of different inter-related components such as molecules, genes, regulatory networks, cells, organoids and tissues, integrated with computational approaches such as design, modeling, simulation and optimization, among others.

The role of information technology in the biofabrication of tissues and organs.

What is ICT role in Biofabrication for Regenerative Medicine
ARTIFICIAL INTELLIGENCE



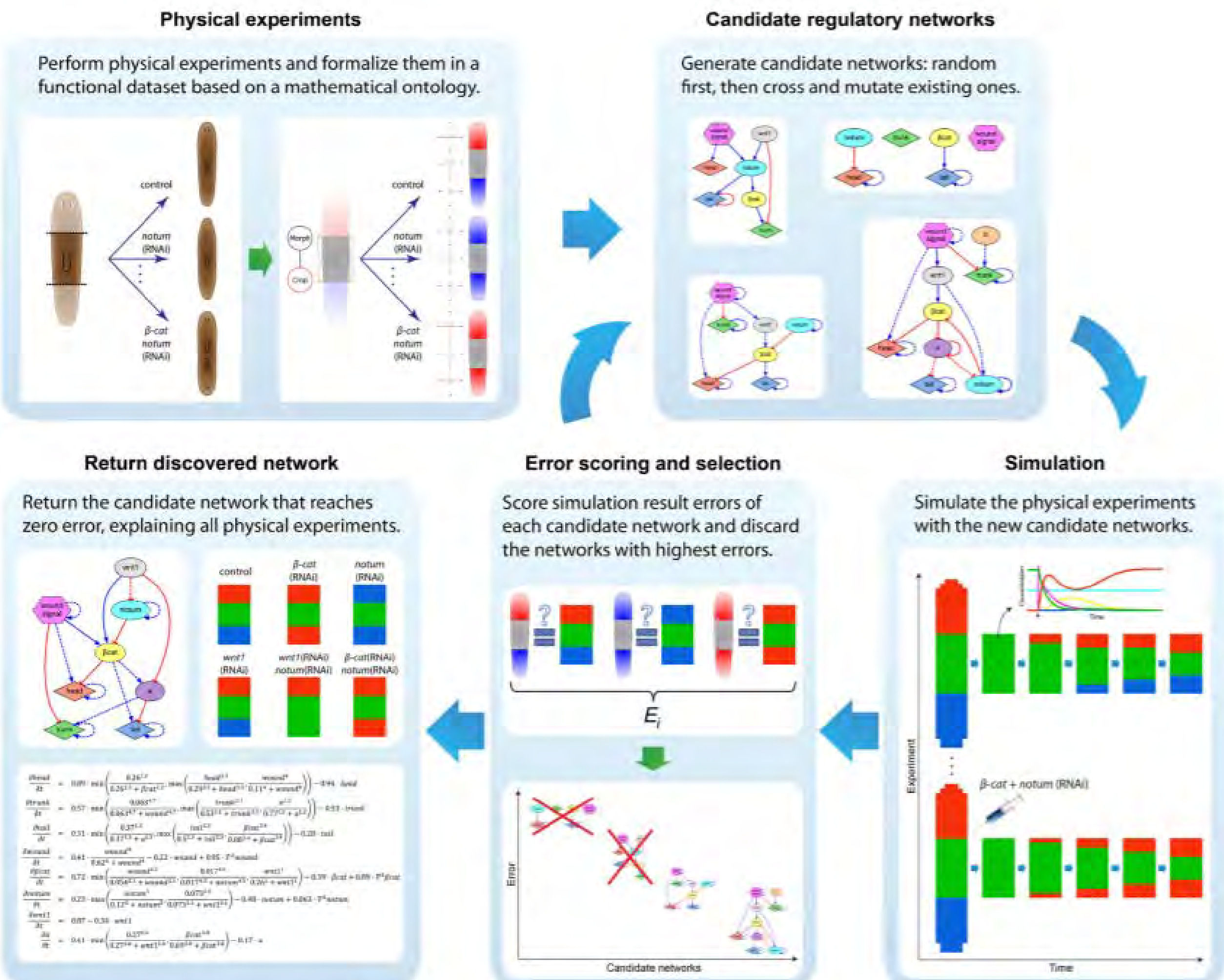
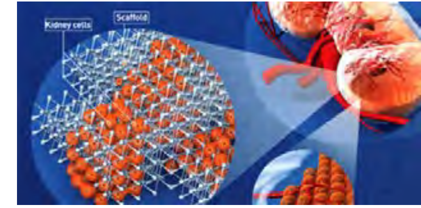


Fig 2. Method to infer regulatory networks from phenotype-based experiments. Taking a dataset of formalized experiments as input, the algorithm cyclically generates candidate regulatory networks, simulates the experimental manipulations, and discards the networks with the highest errors (lowest predictive power); this process is repeated until a network with zero error is found.

doi:10.1371/journal.pcbi.1004295.g002

The role of information technology in the biofabrication of ssues and organs.

What is ICT role in Biofabrication for Regenerative Medicine
ARTIFICIAL INTELLIGENCE ROBOT BIOREACTOR



SCIENCE ROBOTICS | FOCUS

BIOMIMETIC ROBOTS

Growing tissue grafts on humanoid robots: A future strategy in regenerative medicine?

Pierre-Alexis Mouthuy* and Andrew Carr

Humanoid robots may enhance growth of musculoskeletal tissue grafts for tissue transplant applications.

Over the past decade, exciting progress has been made in the development of humanoid robots. The significant potential future value of humanoids includes applications ranging from personal assistance to medicine and space exploration. In particular, musculoskeletal humanoids (such as Kenshiro and Eccerobot) were developed to interact with humans in a safer and more natural way (*1*, *2*). They aim to closely replicate the detailed anatomy of the human musculoskeletal system including muscles, tendons, and bones.

With their structures activated by artificial muscles, musculoskeletal humanoids have the ability to mimic more accurately the multiple degrees of freedom and the normal range of forces observed in human joints. As a result, it is not surprising that they offer new opportunities in science and medicine. Here, we suggest that musculoskeletal robots may assist in the growth of musculoskeletal tissue grafts for tissue transplant applications.

In aging populations, musculoskeletal tissue disorders and injuries are a growing health

static conditions, dynamic stresses applied in vitro generally improve the mechanical properties of engineered constructs and lead to larger cell numbers, greater matrix deposition, and better cell differentiation (*4*–*6*). Moreover, multidimensional strains are known to improve the functionality of engineered tissues (*7*). Overall, the evidence in the literature suggests that mechanical stimulation in vitro should mimic stresses experienced by the tissues in vivo as closely as possible.

3) Enable the fabrication of tissue constructs with dimensions similar to their native counterparts.

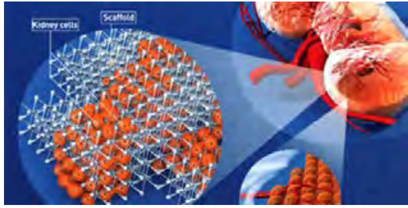
Bearing in mind the above considerations, it makes sense to create advanced bioreactors with structures, dimensions, and mechanics similar to those of the human body. In this context, humanoid musculoskeletal robots become highly relevant. By mimicking the human skeletal architecture and the body movements in different activities, they could help to overcome the limitations of current bioreactors.

Designing "humanoid-bioreactor" systems would involve several considerations, such as the following:

How would the robot interact with its environment? The ability of humanoids to freely interact with their environment and real objects could be an advantage compared with desktop bioreactors. This may provide more realistic stresses to tissue constructs and eventually achieve grafts with better functionality or with tailored properties.

The role of information technology in the biofabrication of tissues and organs.

What is ICT role in Biofabrication for Regenerative Medicine



ARTIFICIAL INTELLIGENCE ROBOTIC MANIPULATION

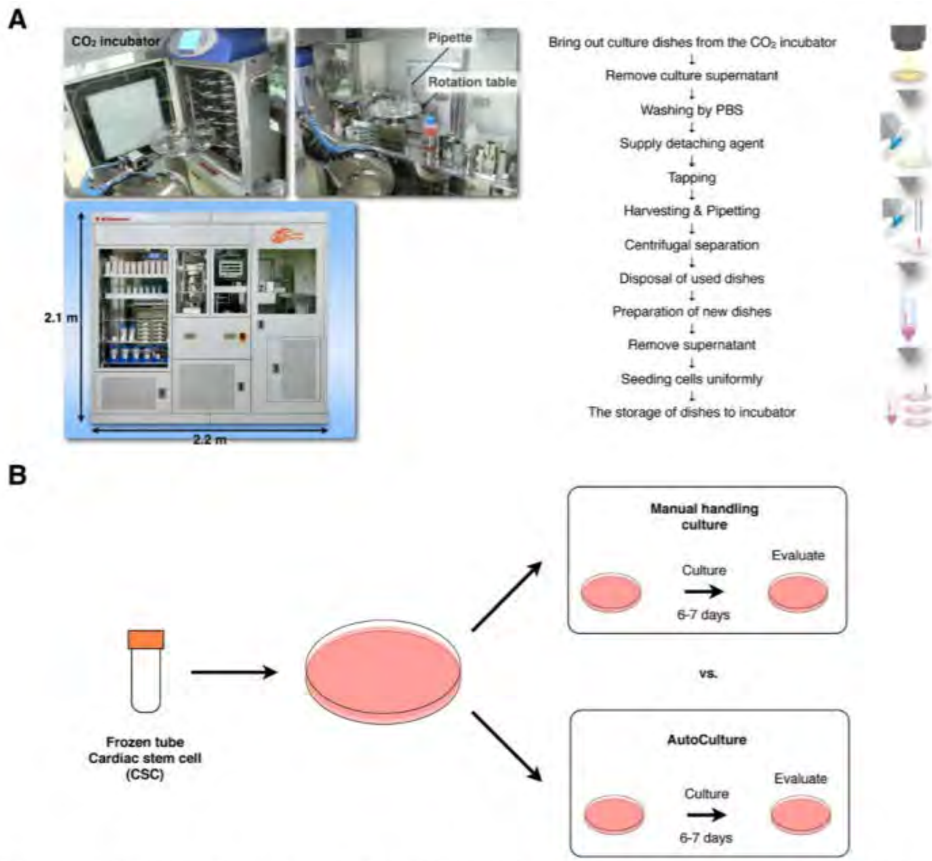
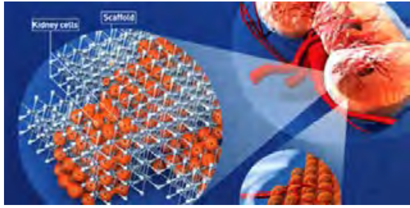


Figure 1 Process maps showing the key steps in human cardiac stem cell culture using manual methods and the AutoCulture® system. **(A)** The automated culture system AutoCulture® by Kawasaki Heavy Industries (left) can automate every step of manual cell culture under current good manufacturing practice (cGMP) grade. **(B)** Schematic representation of the experiment. Human cardiac stem cells (CSCs) were thawed and split into 2 dishes for either manual culture or automated culture using AutoCulture®.

The role of information technology in the biofabrication of tissues and organs.

Biofabrication for Regenerative Medicine and the Digital revolution in Medicine 4.0



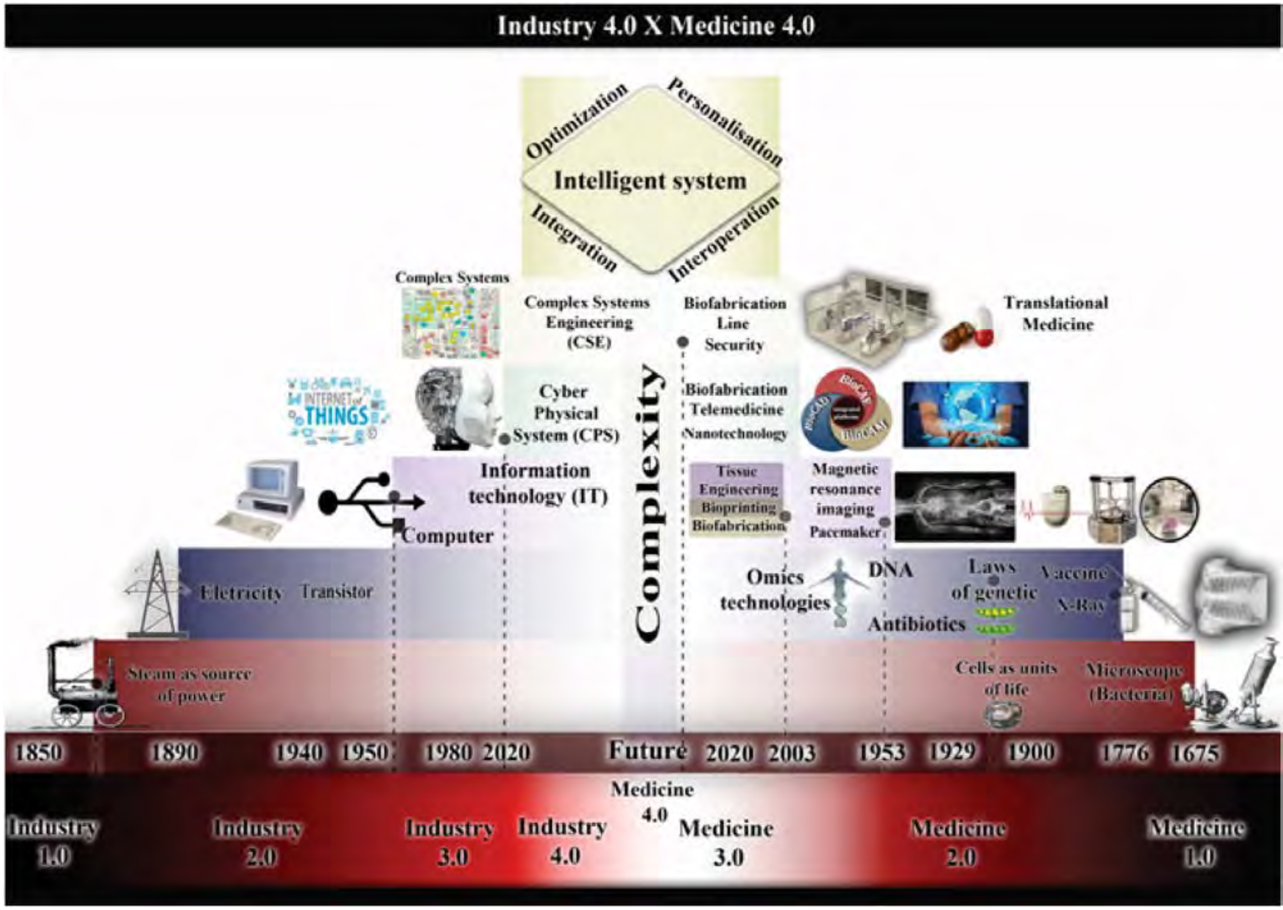
The future of biofabrication should comply with the paradigm of **Medicine 4.0**, the progress toward digitalization, simulations and process optimization, and the production of organs and tissues in a safe and productive way.

From the perspective of **drug development**, biofabrication is closer to realization, opening up the possibility to have a set of microtissues or organoids, used as a combinatory analysis to screen the best drug and the real amount for a specific disease in a combinatory patient-specific solution.

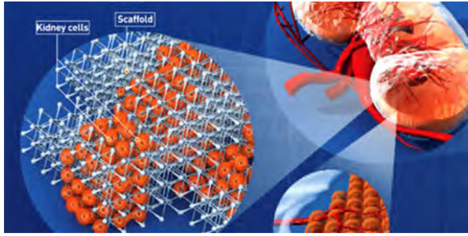
Bioreactors are essential for maturating the fresh organ.

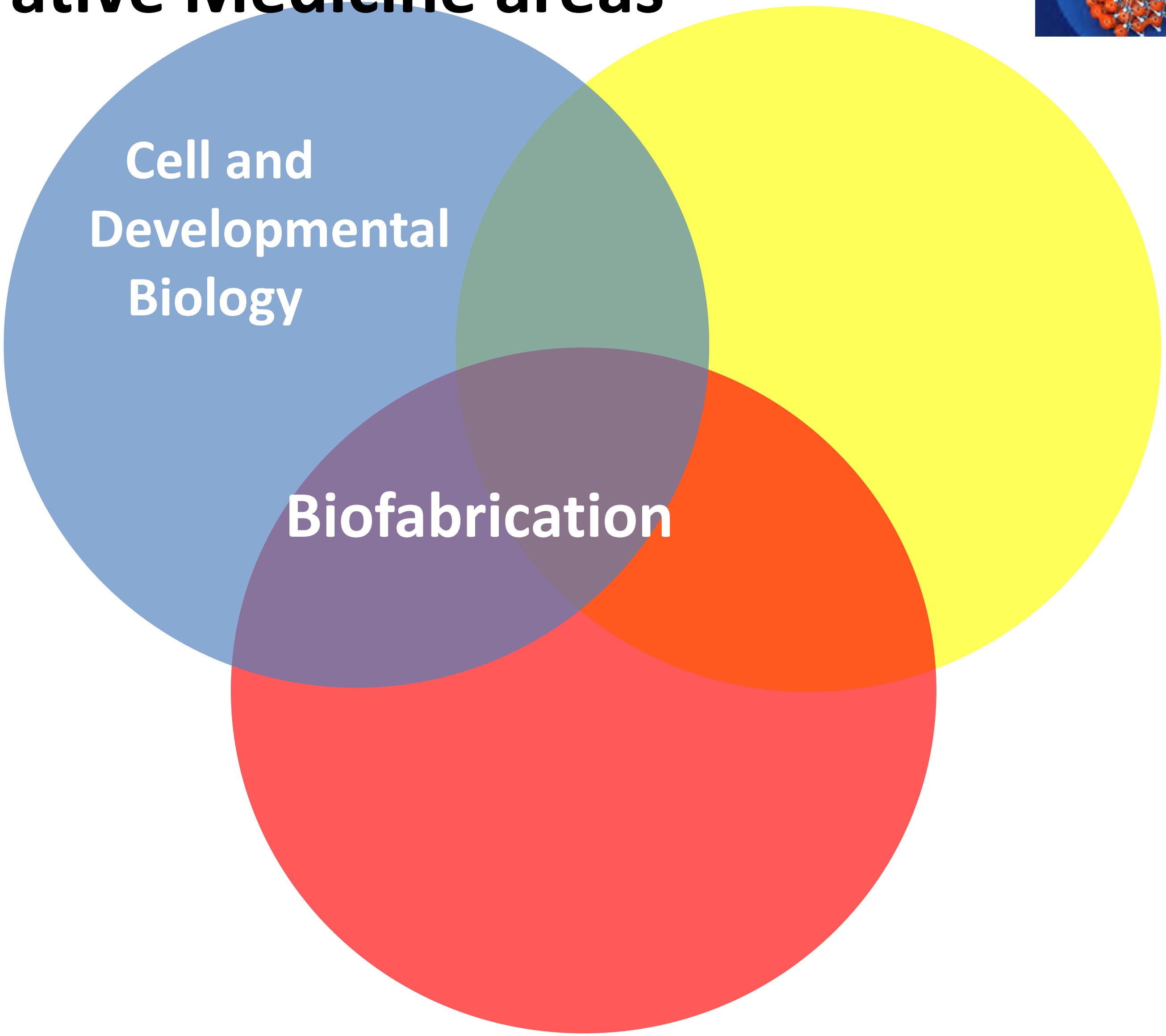
Currently, the bioprinting and maturation steps are separate. This means that the organ is first 3D printed using a bioink and then moved to an adequate chamber to evolve the organ to later be implanted into the patient. In the future, these two devices will likely be integrated into one, which will decrease the risk of contamination and avoid manipulation and transference of live constructs between two pieces of equipment.

Regarding computational biology, the **'omics technologies** already allow us to envision an era of personalized biofabrication in which patients receive customized therapy and customized dosages. In addition, the 'omics technologies integrated with data mining, machine learning, smart devices and others intelligent systems, could build automated production systems of tissues and organs



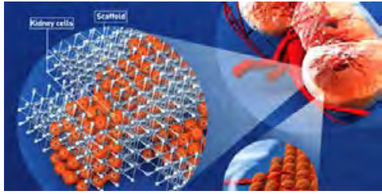
Biofabrication covers Biotechnologies Regenerative Medicine areas



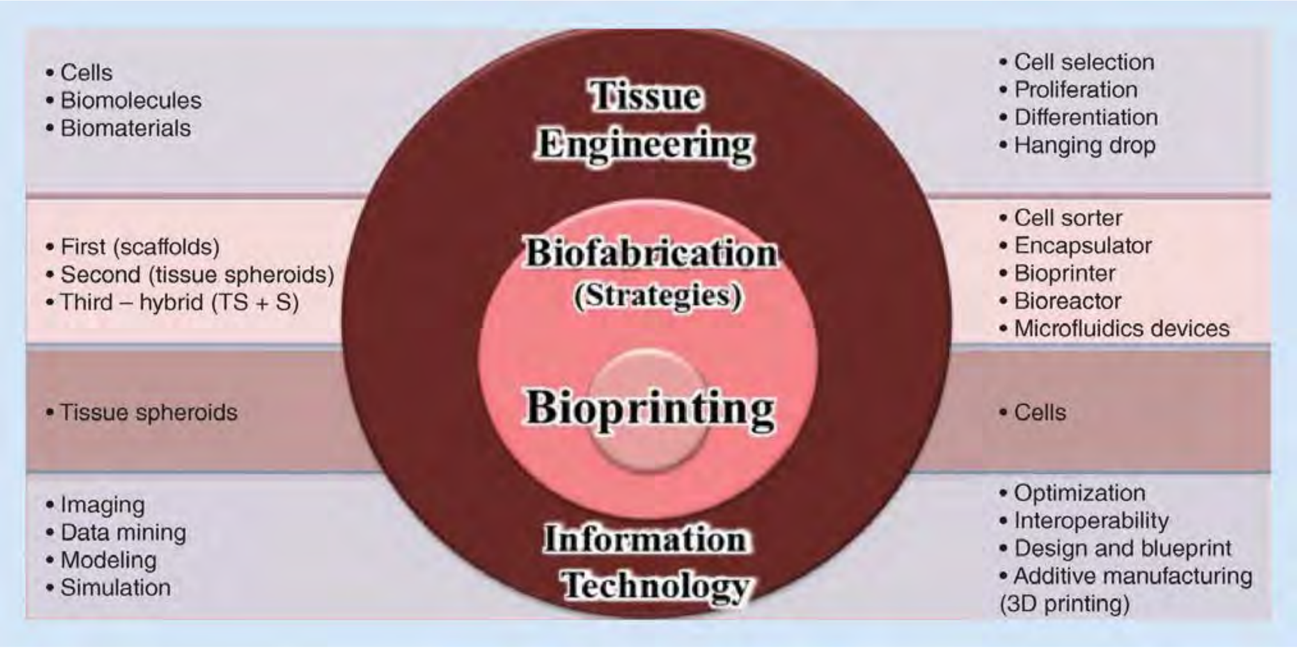


4.0 Biomedical Revolution: Emergence of Convergent Science

What is Biofabrication for Regenerative Medicine: Tissue and Organ Bioprinting



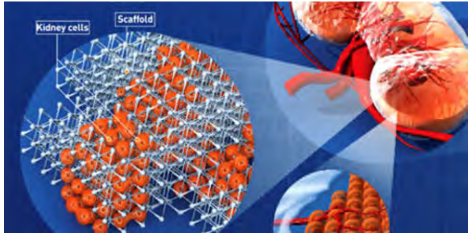
Biofabrication is an area of tissue engineering where many solutions can be developed using additive manufacturing (AM). AM is also known as 3D printing and involves a layer-by-layer material deposition paradigm. This includes the use of different AM techniques, materials, cell types and applications. The figure shows relationships between tissue engineering, biofabrication and the embracing role of IT.



European FET Flagship Project

Biofabrication for Regenerative Medicine.

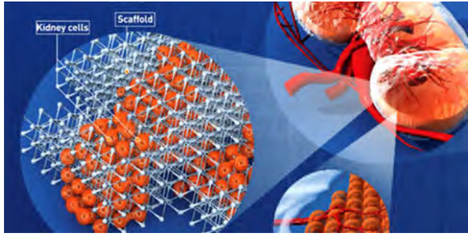
Roadmap – From Cells to Organs



CELLS → ORGANS

Research	Technology	Products & services
Generation of human IPS cells	Reproducible & scalable biofabrication of human IPS cells	Bioreactor for scalable biofabrication of human IPS cells, gene vectors, differentiation factors Cell transplantation
Biofabrication & characterization of functional organoids & minitissues	Sizing, shaping & scalable biofabrication of functional human organoids & minitissues	Automated microtissue biofabricators Micromolding multiwells Models of human diseases Drug toxicity & drug discovery assays Microtissue transplantation
Biofabrication of functional vascularzied & perfusible mini-organs	Microfluidics & minibioreactors based perfusion technology Organ-on-a-chip	Microfluidic devices Microfluidic 3D printer Microfluidic hydrogels Sacrificial hydrogels In vitro model of human organs
Biofabrication of functional & vascularized artificial living human organs	3D biofabrication & bioprinting of functional human organs	Medical Imaging, CAD softwares, Digital Models of Human Organs, DataBases, 3D Bioprinters, Perfusion Bioreactors, Non-invasive Biomonitoring, Biosensors, Human Organs for Transplantation In situ Robotic Bioprinters and Bifabricators

Evolution of Biofabrication for Regenerative Medicine



Today

2011-2016:

Small-scale tissues for regenerative medicine, drug discovery and toxicity testing

Tomorrow

2016-2020:

Simple tissues for implant (e.g. cardiac patches or segments of tubes, like blood vessels

Future Reality 2020-2030:

Lobs or functional units of organs

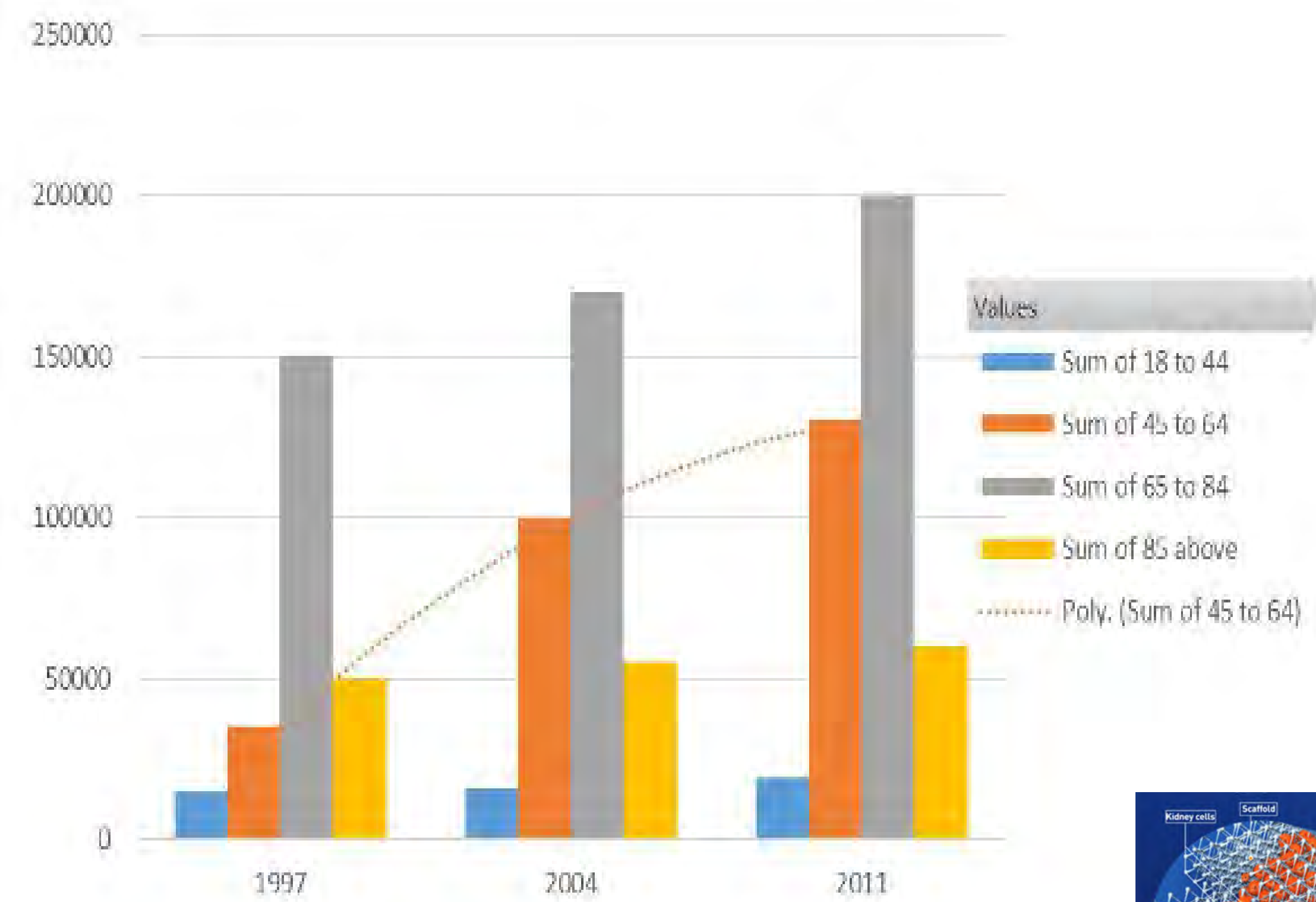
Future

2030>:

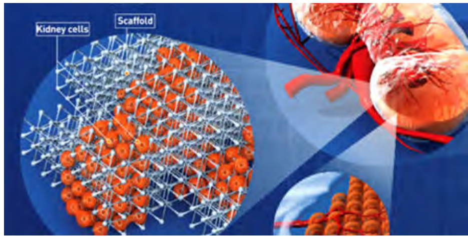
Full organs

Orthopedic Implants

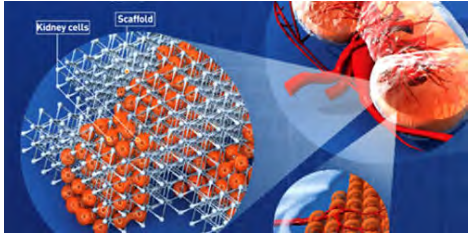
The number of USA people in need of orthopedic implants has risen drastically in the past few years and the international market for orthopedic instrumentation is expected to reach about **$56 billion by 2017**.
The number of people between the ages of 45 and 60 in need of such implants has risen sharply. According to some industry estimates, ***80% of global implants will be made by bioprinting*** *in the coming two decades*.

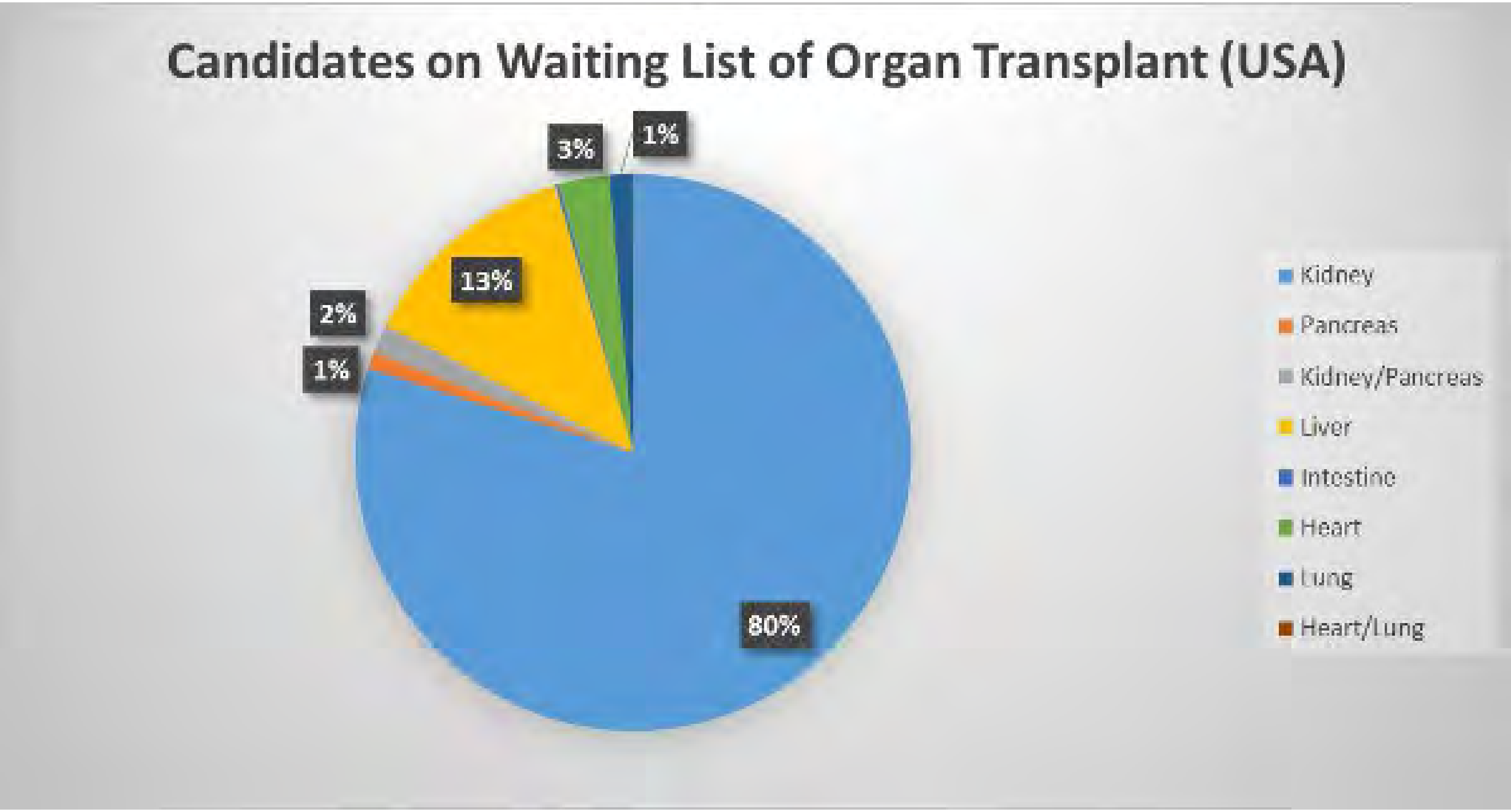


Distribution of adults in need of a knee replacement in the U.S.
(Source: Agency of Healthcare Research and Quality)

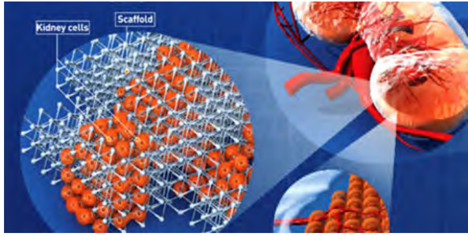


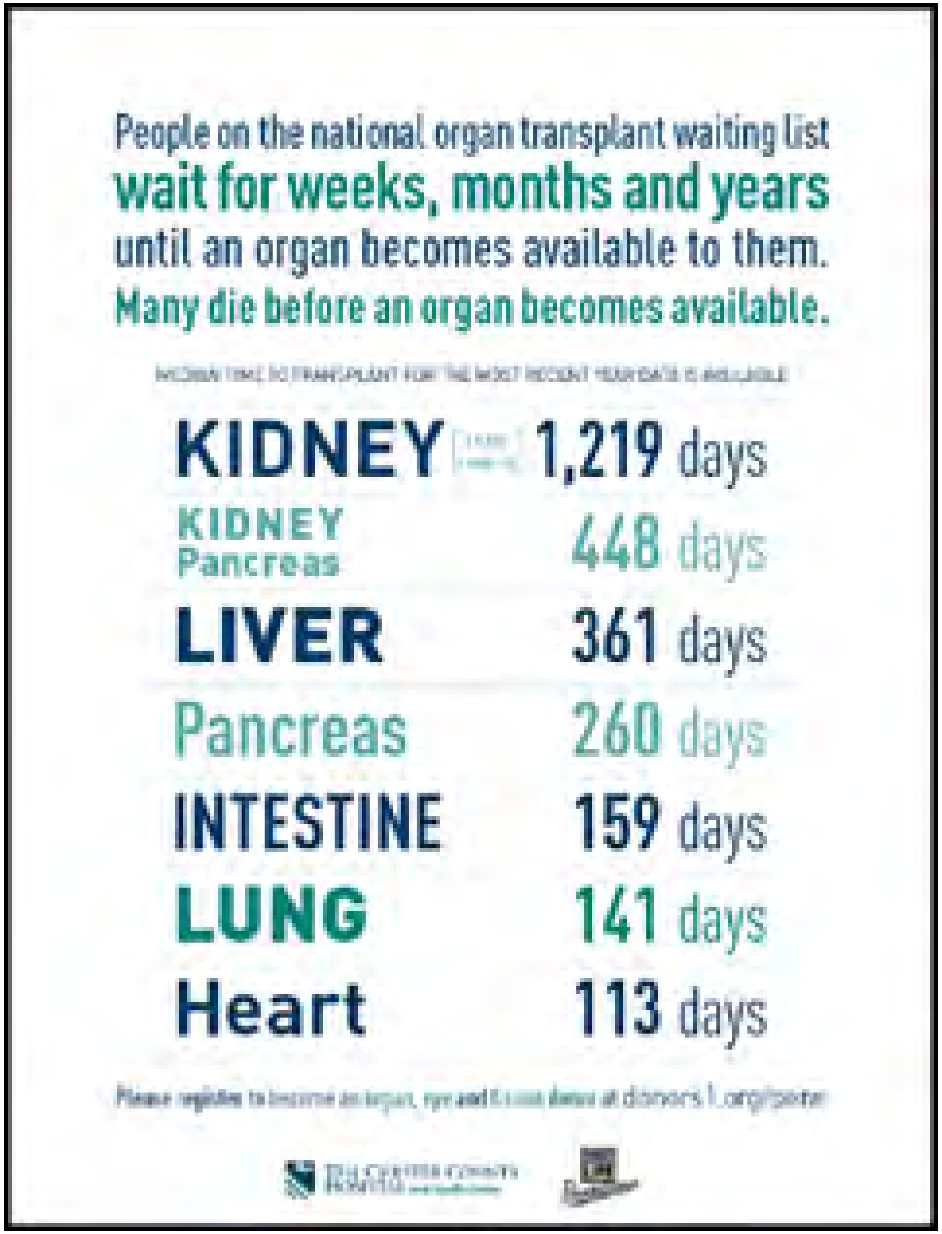
160.000 PATIENTS IN USA WAITING LIST FOR ORGAN TRANSPLANTATION

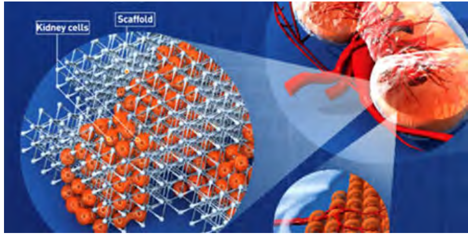




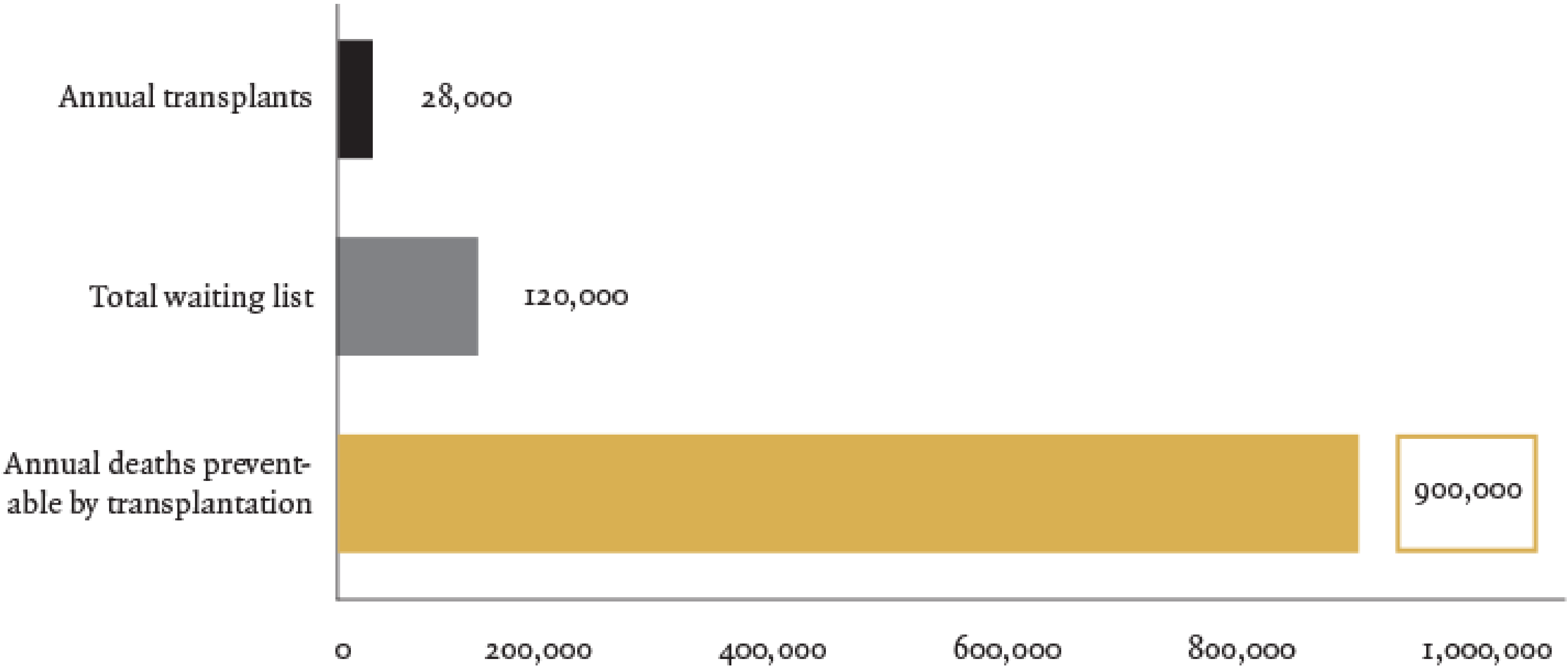
MEAN DAYS IN WAITING LIST



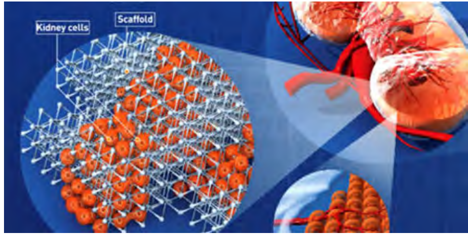


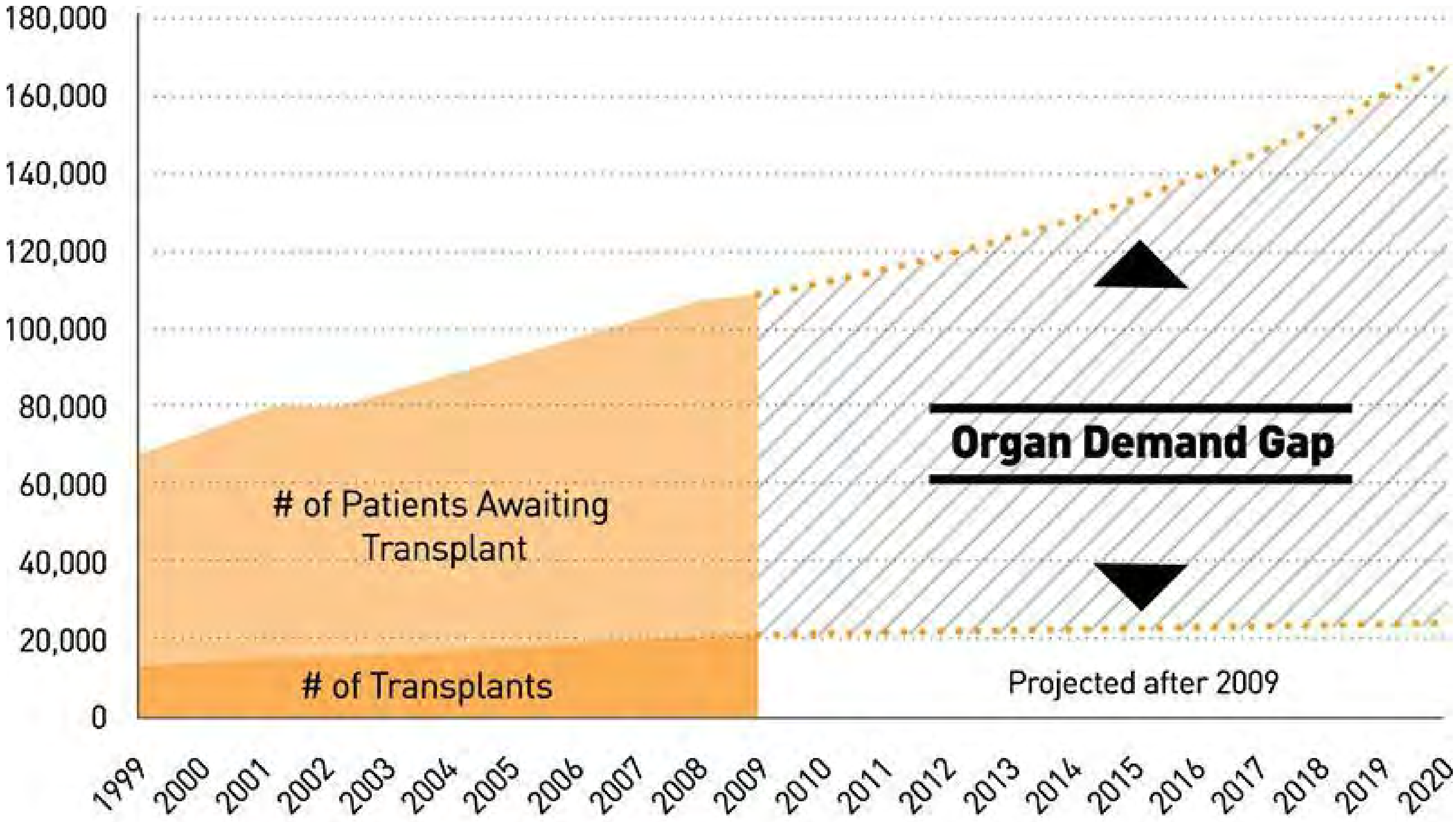


KIDNEY TRANSPLANTATION IN USA

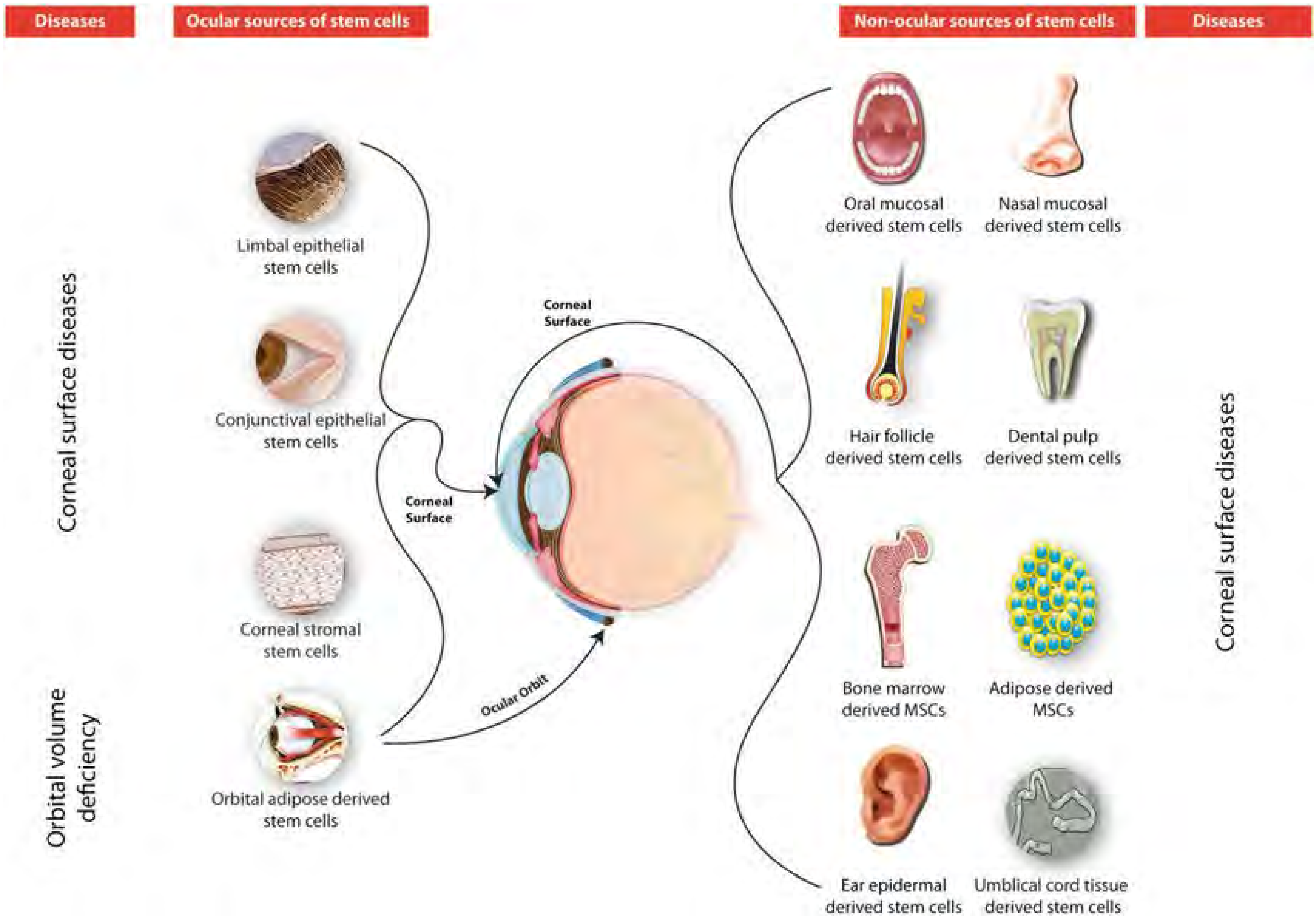


KIDNEY TRANSPLANTATION DEMAND GAP

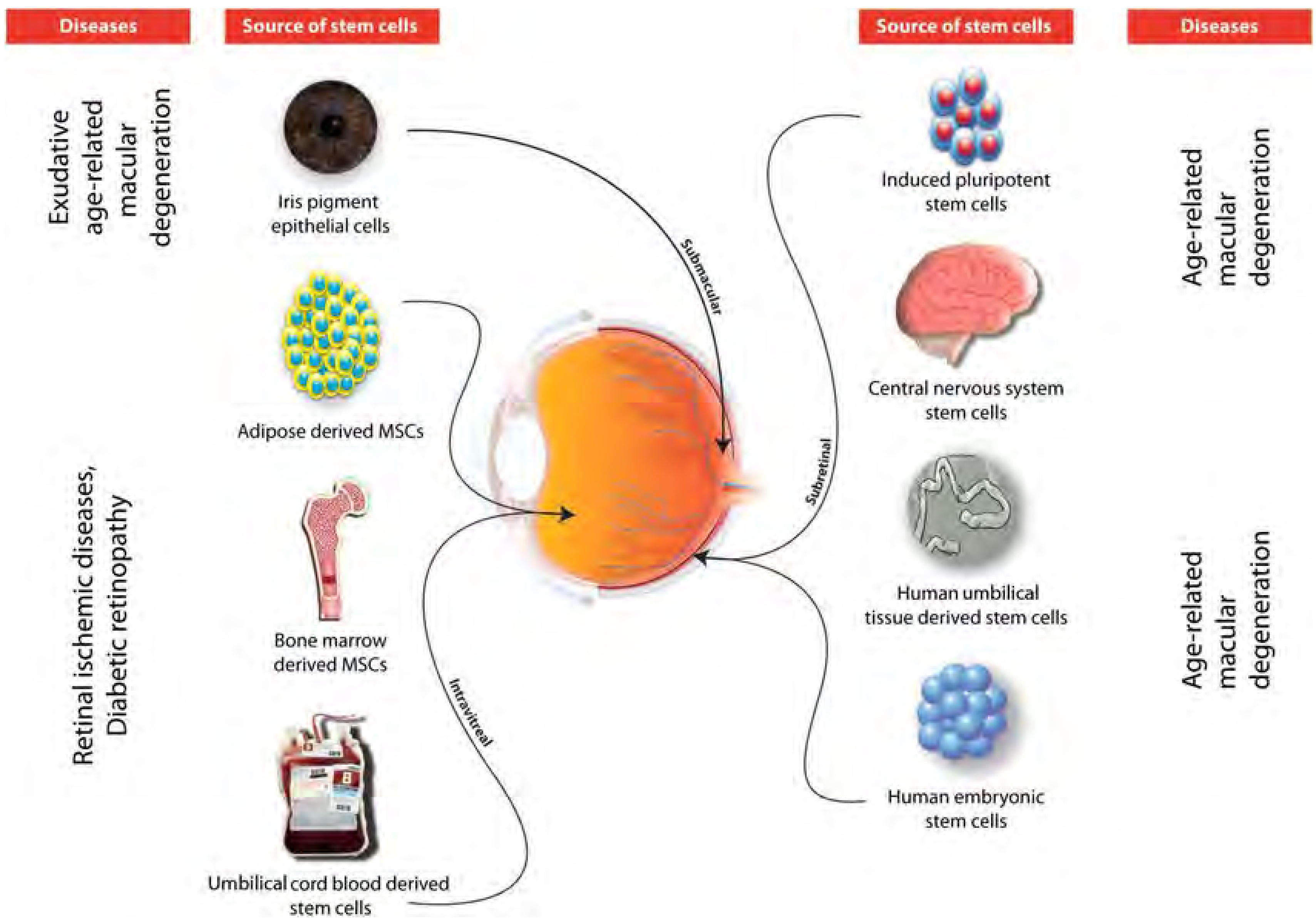




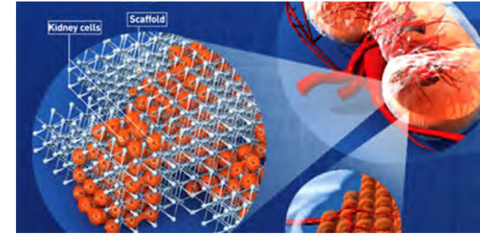
SENSORY RESTORATION CORNEA

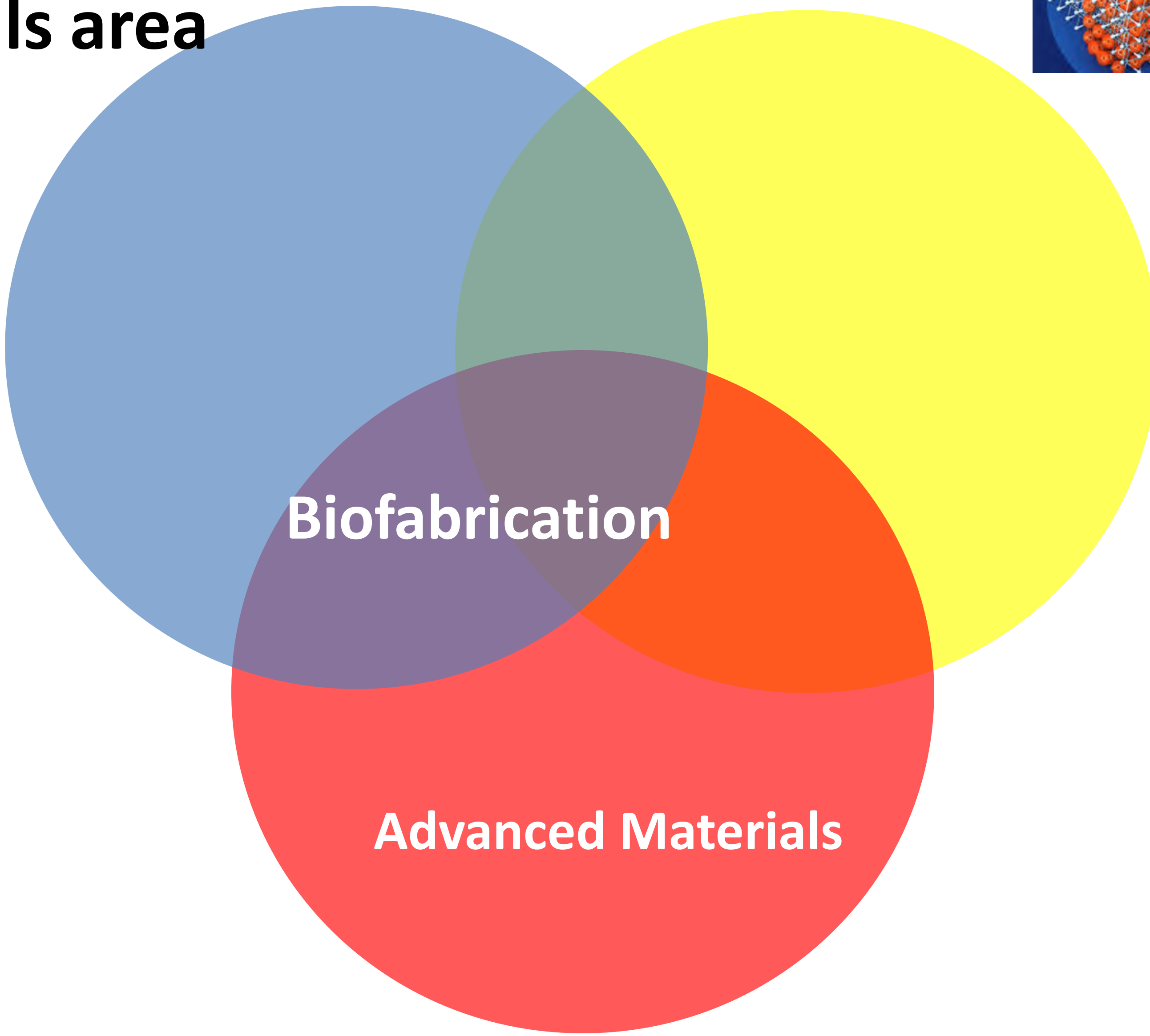


SENSORY RESTORATION RETINA



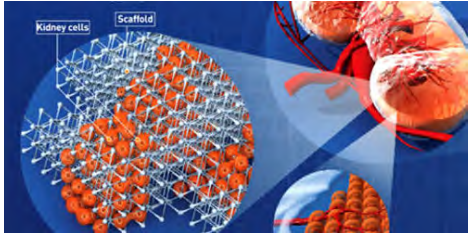
Biofabrication for R.M. covers Advanced Materials area

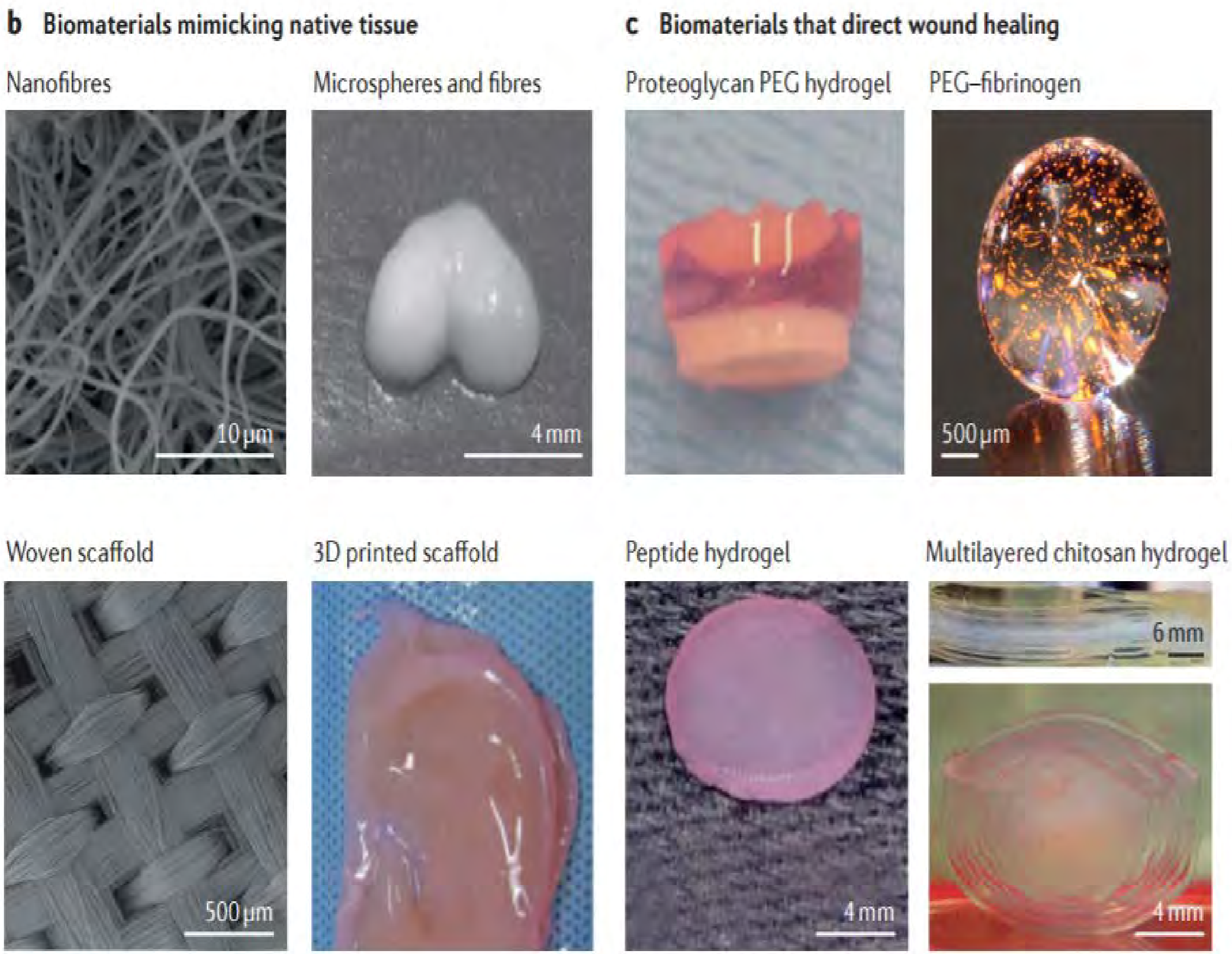


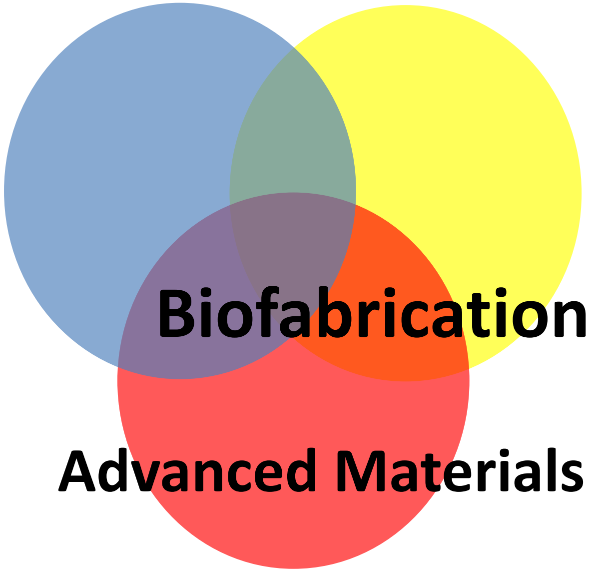


4.0 Biomedical Revolution: Emergence of Convergent Science

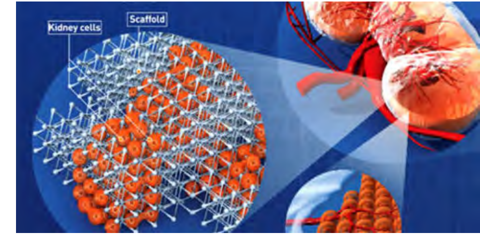
Biofabrication for R.M. covers Advanced Materials area





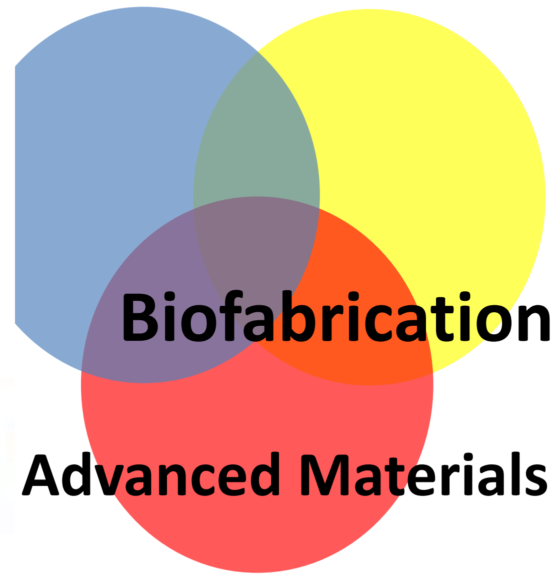


Biofabrication for R.M. covers Advanced Materials area

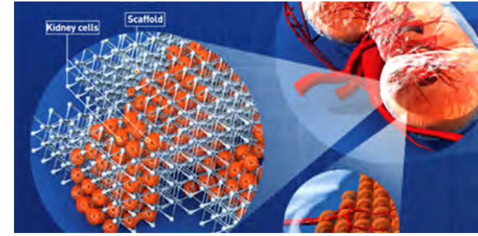


Some of the commercially available skin substitutes that have been successfully used in clinical practice.

Brand name/manufacturer	Scaffold material	Cells	References
Dermagraft® Advanced Biohealing, Westport, CT, USA	PGA and PLA fibers and silicon film	Fibroblasts	Hart et al. [35]
Apligraf® Organogenesis Inc., Canton, Massachusetts, CA, USA	Bovine collagen	Keratinocytes and fibroblasts	Falanga et al. [36]
OrCel® Ortec International, Inc., New York, NY, USA	Bovine collagen sponge	Keratinocytes and fibroblasts	Still et al. [37]
TissueTech Autograft System (Laserskin® and Hyalograft 3D®) Fidia Advanced Biopolymers, Abano Terme, Italy	Hyaluronic Acid	Keratinocytes and fibroblasts	Caravaggi et al.[38] Uccioli et al. [39]
Matriderm® Dr. Suwelack Skin & Health Care, Billerbeck, Germany	Acellular dermal substitute	Keratinocytes and fibroblasts	(Figure 3) -Micheal et al. [40] Min et al. [41]



Biofabrication for R.M. covers Advanced Materials area



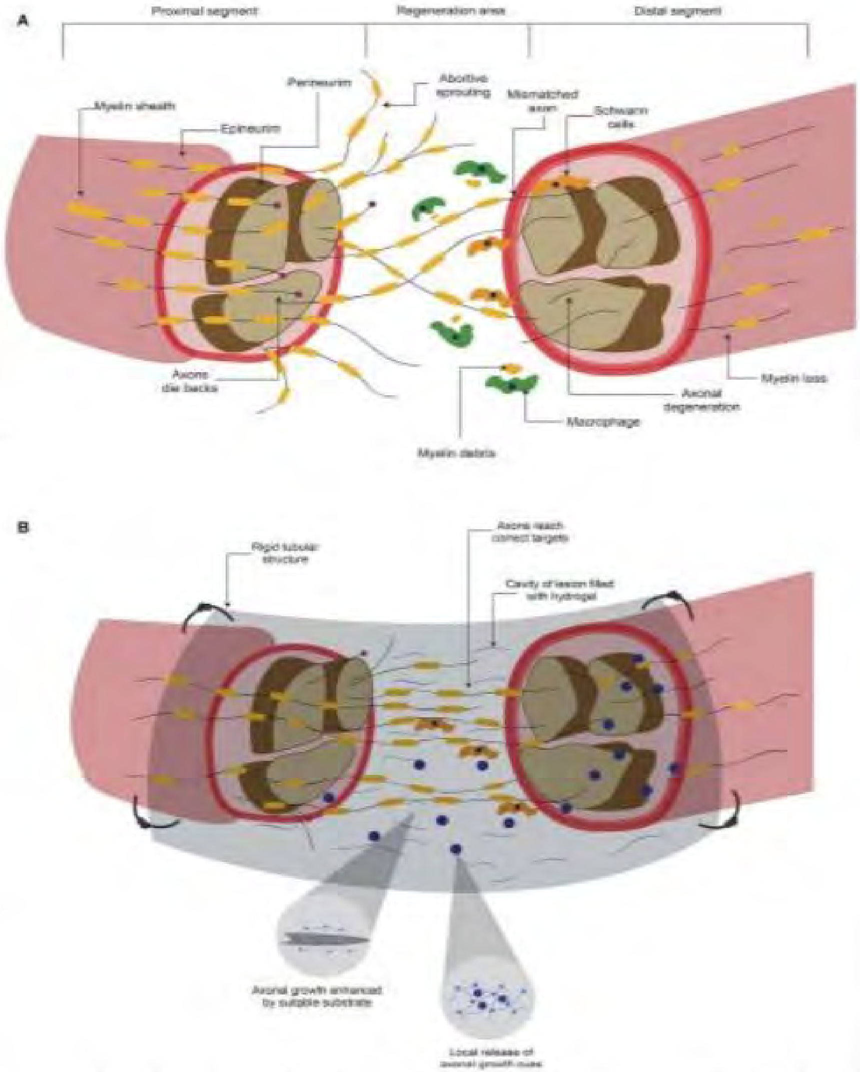
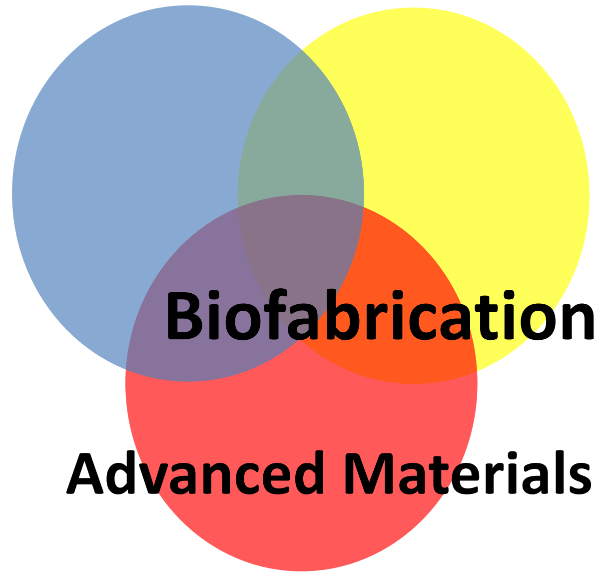
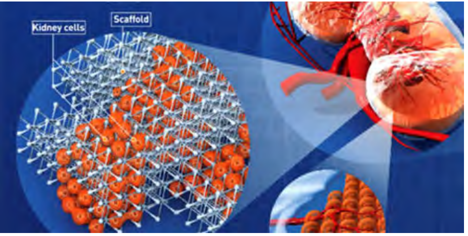


Figure 5. Hydrogels promote axonal regeneration after a peripheral nerve lesion. (A) After a lesion where peripheral nerves are severed, inhibitory elements for axonal regeneration arise either in proximal or in distal segments. Although there can be regeneration to unite both stumps, it is common that mismatches are formed. (B) When the lesion area is connected with a rigid tubular structure, and this is filled with a hydrogel, there is a mechanical support and a suitable





Biofabrication for Regenerative Medicine: Ambition

1. Developing manufactured functional tissues and organs, thus eliminating transplantation waiting lists;

2. Developing advanced 3D *in vitro* models to better understand pathological mechanisms and advanced therapies for rare and life-threatening diseases;

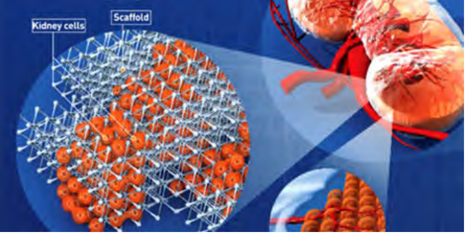
3. Developing new drugs and enable repurposing of existing off-the-shelf medicines through 3D *in vitro* models, identifying the most effective therapies for patients;

4. Produce tissues and organs generating less immune reaction than donor tissues;

5. Stimulating new regenerative medicine and biofabrication industries;

6. Transforming traditional surgical practice by personalized *in situ* robotic bioprinting of advanced therapies;

7. Creating a hub between partners that will guarantee professional knowledge diffusion and democratic access to new regenerative medicine therapies through biofabrication and organ-on-chip technologies;



Biofabrication for Regenerative Medicine: Impact

1. The first integrated artificial organ biofabrication line as a prototype clinical printing room;

2. Good manufacturing practice (GMP) Robotic 3D bioprinters for use in the operating theatre;

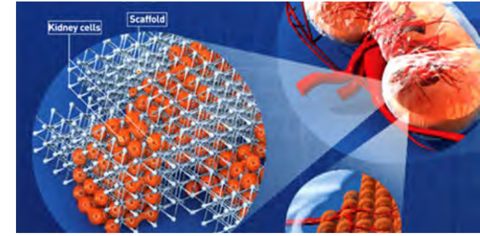
3. Human 3D mini-tissues and -organs for bioreactor-based high throughput automated screening and analysis for toxicity assays, drug development and other relevant industries, working towards personalized drug treatment and testing;

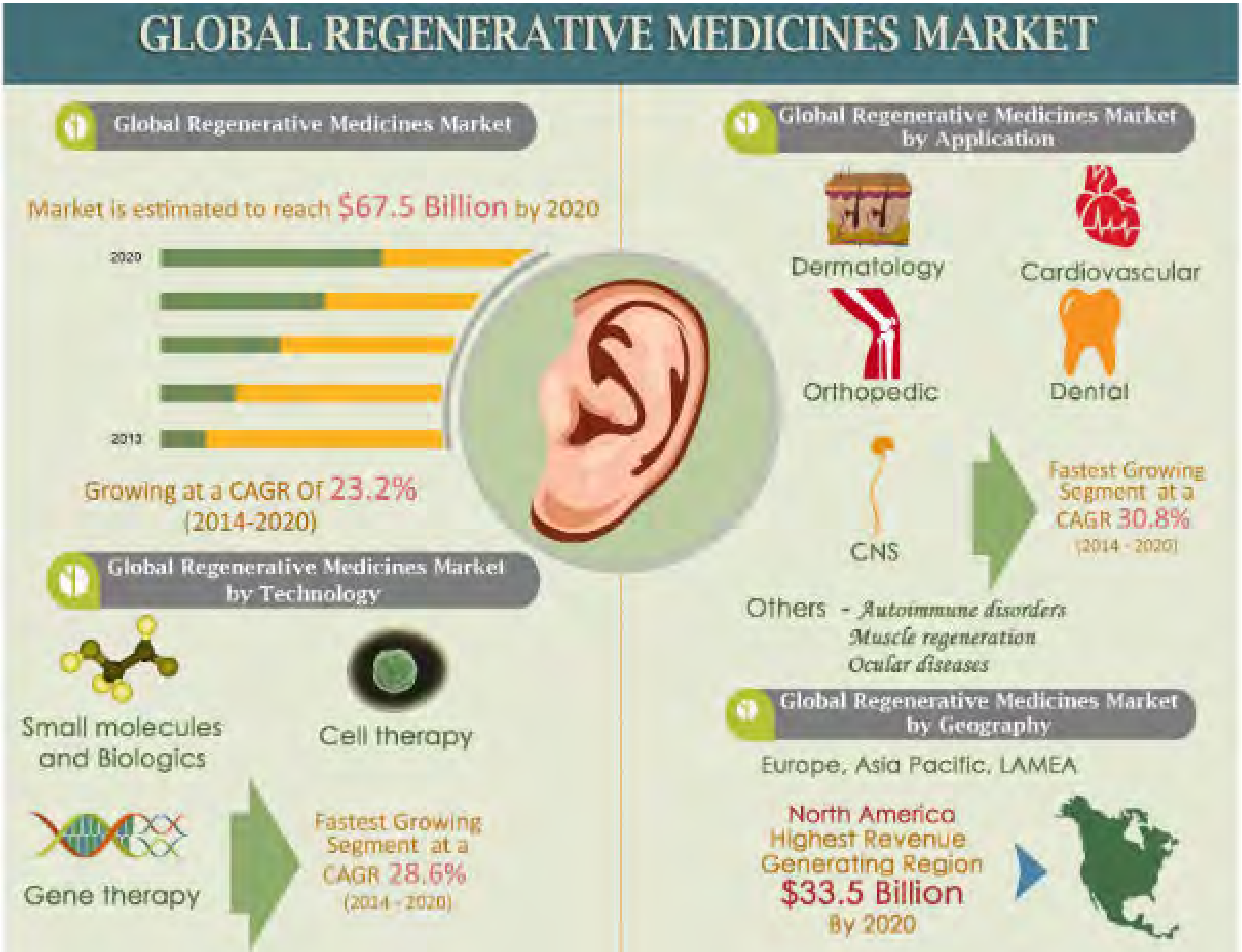
4. An open access database with digital information including models of human 3D tissues and organs to improve strategies and approaches developed for new therapies.

5. European network for basic research, GLP safety testing of biomaterials, GMP production guidelines and facilities, required standardization and quality control strategies for advanced therapies validation and translation;

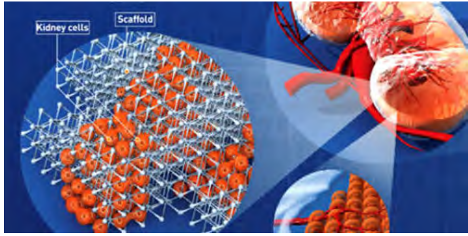
6. Automatization of procedures and workflows necessary to lower the barrier to market entry for advanced therapies;

Biofabrication for Regenerative Medicine: Global Market Forecast





3D Bioprinting Market Size To Be Worth $1.82 Billion By 2022

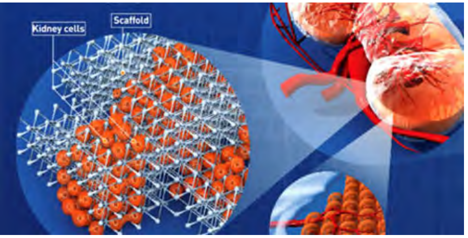


Global 3D bioprinting market is expected to reach USD 1.82 billion by 2022, according to a new report.

Rising prevalence of chronic diseases such as Chronic Kidney Disease (CKD) which demands kidney transplantation is expected to boost the market growth, as 3D bioprinting is convenient and cost effective substitute for organ transplantation.

Emerging medical applications of 3D bioprinting such as toxicity testing, drug discovery, tissue engineering and consumer product testing are expected to further drive the market growth positively. Increasing R&D expenditure is anticipated to be high impact rendering driver for the industry.

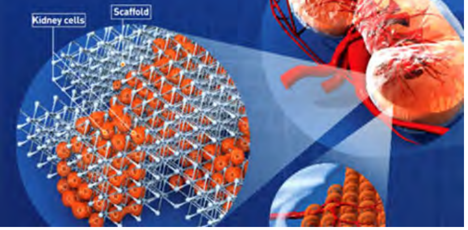
3D bioprinting advances in tissue engineering and allows developments to be done using biomaterials which have better biocompatibility. Moreover, rising geriatric population is expected to assist the market growth, as this demographic is highly susceptible to age related organ deformities.



Biofabrication for Regenerative Medicine: Integration

Integration of different EU Communities:

- Physicists;
- Chemists;
- Biologists;
- Clinicians;
- Robotic/Mechanical and Biomedical Engineers;
- Pharmacologists;
- Computer scientists;
- Mathematicians.



Biofabrication for Regenerative Medicine: Need for Europe

1. Improve European healthcare, and the lives of ageing European citizens;

2. Guarantee citizens access to the new regenerative therapies and personalized medicine;

3. Activate structural exploitation of research results dynamics in order to maximize the impact of scientific activities and stimulate the growth of derived innovative value chains;

4. Standardize academic research and commercial production of fabricated therapies;

5. Lead the development and convergence of biofabrication, organ-on-chip and regenerative medicine;

6. Create coherence within the rapidly emerging biofabrication industry;

7. Stimulate the cosmetic, pharmaceutical, agriculture, food and robotic industries.

Biofabrication for Regenerative Medicine:68 Stakeholders

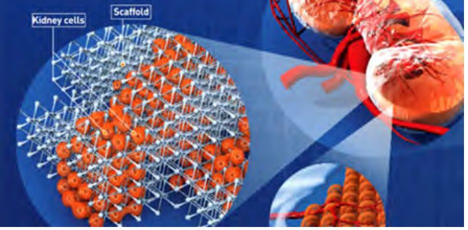
Academics (incomplete list):

- Netherlands:
  - Utrecht (Malda, Clevers); Biofabrication, Skeletal, Intestine
  - Maastricht (Moroni, van Blitterswijk); Biofabrication, Kidney/Pancreas
  - Twente (van den Berg; Stramigioli); organ on chip; robotics;
  - Eindhoven (Dankers); hydrogels
  - Rotterdam (van Osch); Cartilage
- Germany:
  - Wurzburg`Groll, Dalton); Biofabrication, biomaterials
  - Berlin (Duda); Bone
  - Hannover (Chichkov); Aachen (Gillner;) Laser Biofabrication
  - ‘Hamburg, Thomas Eschenhagen, Heart vitro, Pharmacology
  - Charitè Hospital and Berlin-Brandenburg Center for Regenerative Therapies (BCRT)
- France:
  - Paris (Sahel); Opthalmology
  - Lyon 3D Fab (Marquette); Biofabrication
  - H Petite, Bone
- Portugal:
  - Porto (Granja); bioprinting, hydrogels
  - Minho (Reis); Biomaterials
- Spain:
  - Barcelona (IBEC); Biomaterials; Biofabrication
  - San Sebastian (Tecnalia); Nanosafety
- UK
  - Strathclide (Shu); Biofabrication, Pancreas
  - Manchester (Derby); Bioprinting, fundamentals of droplets
  - Edinburgh (Melchels); Biofabrication
  - Keele University (El Haj); Bioreactors
  - Nottingham University (Shakesheff) Biomaterials – building blocks
  - London (UCL-Phillips and ICL-Stevens); Nerves and biomaterials
  - Southampton Richard Oreffo Organoids – bone , STEM

- Industrial (incomplete list):
  - Lipogems, human adipose tissue minimal manipulation
  - Envisiontec. Biofabrication industry
  - Poietis; Laser Biofabrication Industry
  - Regemat 3D; Bioprinting Industry
  - GMP centre UK Catapult
  - MolMed; gene therapy with GSK
  - Chiesi; rare disease cell therapy
  - Regenhealthsolutions; regulation consultancy
  - COMECER; isolation technology
  - 3D Bioprinting Solutions; Bioprinting
  - RegenHU; Bioprinting
  - HoloStem; Stem Cells
  - Officine Ortopediche Rizzoli: biomaterials, orthopedic devices, bioprinting

- Italy
  - Pisa (Vozzi); Biofabrication, Sensing
  - Genova (Scaglioni); Bioreactors
  - Trieste (Giacca); Heart, miRNA
  - Trento (Migliaresi, Motta); Biofabrication, biomaterials
  - Milan San Raffaele (Martino); neuroregeneration
  - Modena (De Luca); epithelial cells eye, bladder, urethra
  - Bologna (Calza); GLP preclinical studies and neuroregeneration,
  - Palermo (ISMETT); liver regeneration
  - Naples (Ambrosio); Biomaterials
  - Rome Italian National Institute of Health; cell therapy and regulation
  - ENEA; electromagnetic fields
- Austria
  - Wien (Ovsianiov; Heinz; Ertl);Knoblich; Biofabrication, Vascularization, Vivo imaging; gene therapy; brain organoids; microfluidics
  - Salzburg (Traweger); Tendon
- Switzerland
  - Zurich (Zeonbi Wang; Ehrbar); biorpinting, Designer Biomaterials as building blocks
  - University hospital Basel (Ivan Martin; Andrea Banfi) Fully translational; Angiogenesis
  - EPFL Lausanne (Matthias Lutolf) Biomat/ Biomechanical Influences
  - AO Foundation, Davos (Geoff Richards, Mauro Alini) Bone and Disc
- Poland
  - Warsaw (Wojtek Swiszkowski); Biofabrication, modeling
- Belgium
  - Gent (Dubruel, Vlierberghe); Biofabrication, biomaterials
  - Leuven (Luyten, Geris); skeletal, modeling
- Croatia
  - Ruder Boskovic Institute , Zagreb
- Estonia
  - University of Tartu
- Greece
  - Crete (Stratakis; Chatzinikolaidou); Laser Fabrication/Modification
  - Patras (Burganos); Structural analysis
- Finland
  - Oulu (Seppo Vanio); Developmental Biology; Oganoids
- Sweden
  - Gothenburg (Gatenholm at Chalmers); Cartialge Bioprinting; Education
  - Uppsala (Jöns Hilborn, Biomaterials) Past Presid. TERMIS Int
  - Stockholm, Stephen Strom, Liver
- Romania
  - Timisoara (Neagu); Biophysics
- Ireland

Galway (Pandit, Zeugolis); Biomaterials, Tendons, Spinal Chord;
Dublin (Fergal O Brien); Nanomaterials, Gene therapy

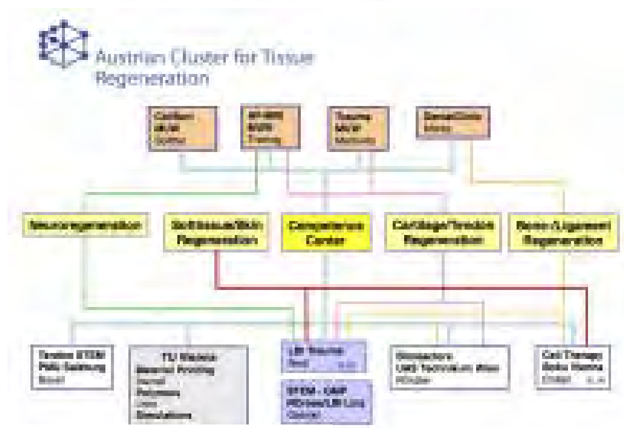


Biofabrication for Regenerative Medicine: Supporting European organisations

IRMI Italian REGENERATIVE MEDICINE Infrastructure

ISBF International Society for Biofabrication

termis® Tissue Engineering International & Regenerative Medicine Society



IDBN Italian Digital Biomanufacturing Network

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Holland. Life Science and Health Sector

3d fab PRINTING FOR LIFE

icbms Mateis LABORATOIRE DE CHIMIE

INSA