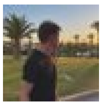
Twitter Thread by Alessandro



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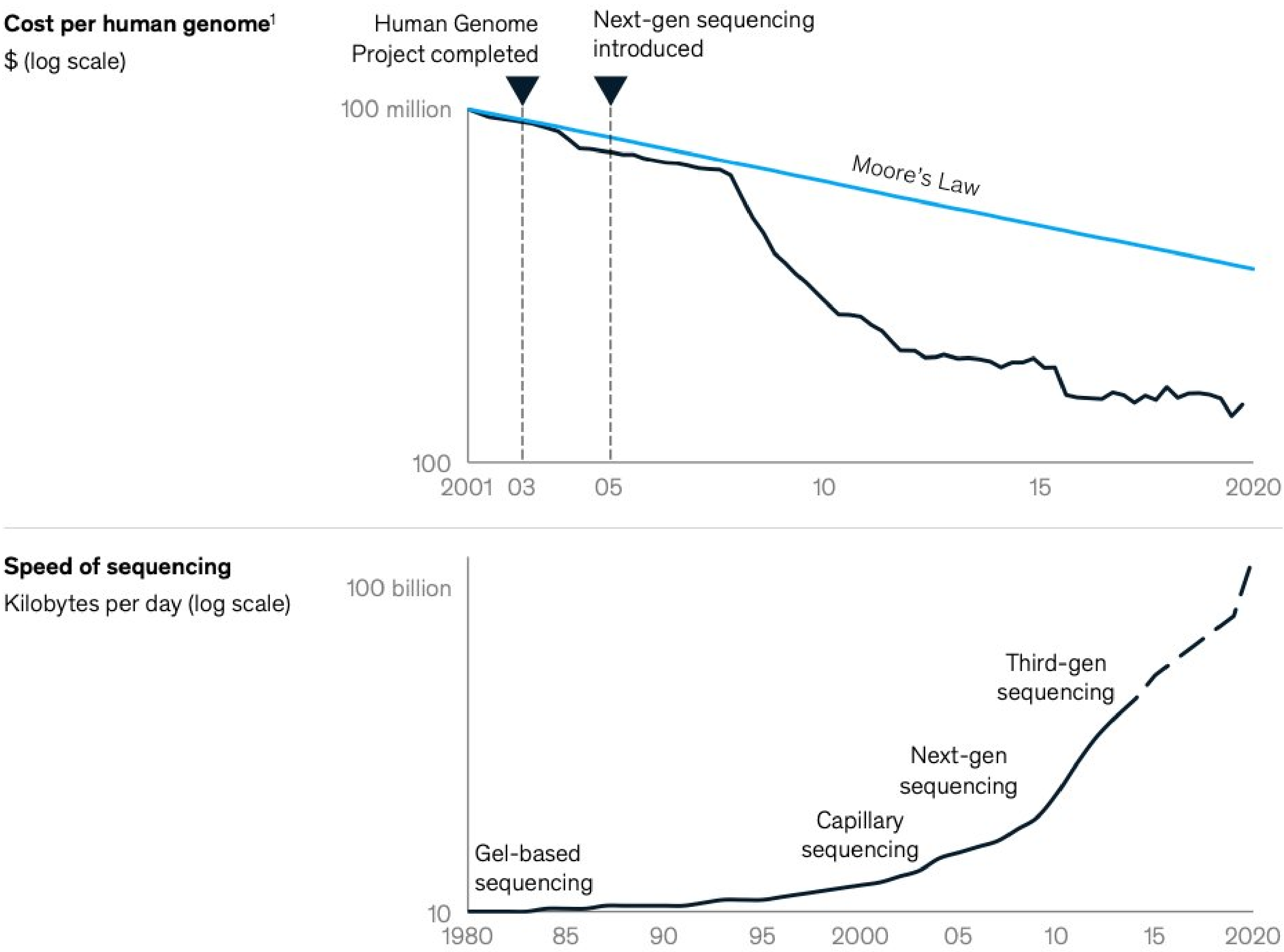
- Thread The Bio Revolution -

McKinsey published a 200-pages report on the impact of biotech in May earlier this year and I want to summarize the most important points for you today.
Feel free to reach out and I will send you the whole report.

1) Introduction

Lately, there has been a sharp drop in the cost of sequencing DNA and emerging technologies to edit genes and reprogram cells have helped to increase innovation. Scientists suggest that 60% of physical inputs in the global economy could be produced biologically.

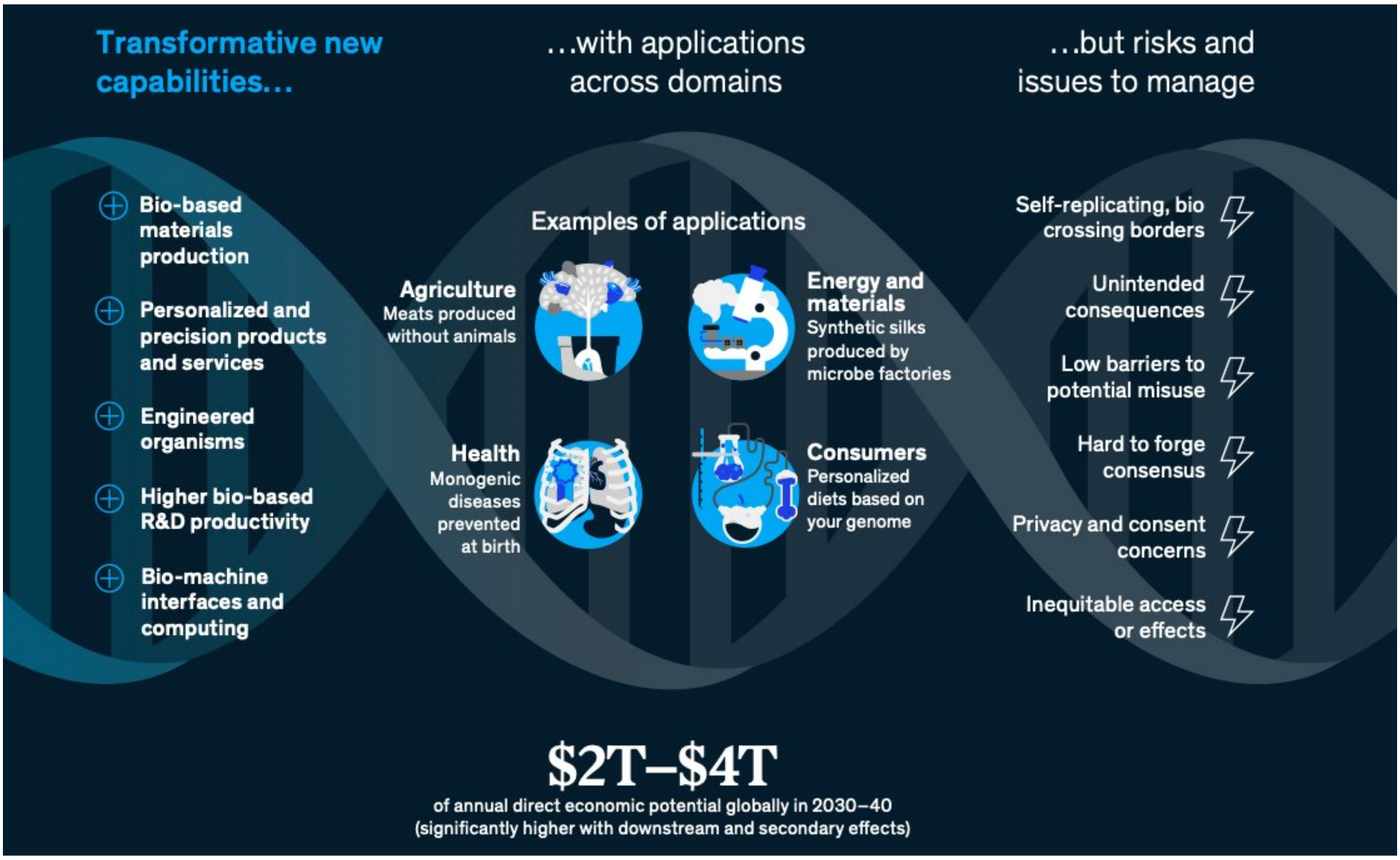
Rapid advances in computing, bioinformatics, and AI are enabling the analysis of omics data.



1. Data do not capture all costs associated with genome sequencing and include only production-related costs (labor, instruments, informatics, data submission).

Source: National Human Genome Research Institute; www.yourgenome.org; McKinsey Global Institute analysis

Of this 60%, 1/3 are biological materials and 2/3 aren't but could be produced or substituted using biology. 45% of the current global disease burden could be addressed using science that is conceivable today. Combining all the use cases that are available today



would make up for an economic impact of up to $4 trillion a year over the next 10-20 years and that doesn't even include applications that haven't yet emerged. However, 70% of the potential impact depends on social attitudes towards technologies and regulations of governments.

Overview of methodology for estimating direct economic impacts.

Scope and factors in our assessment	Included	Excluded
Technology Applicability	• Mapping and engineering of biomolecules, biosystems, biomachine interfaces, and biocomputing	• Mature technologies out of scope (eg, small molecules, biologics, genetically modified crops)
Development phase Maturity of use cases	• Scientifically conceivable today and plausibly commercialized by 2050 (eg, CAR-T therapies for solid tumors) • Use cases that are not yet scientifically feasible and are still in research phases (eg, microbiome-based skin-care products)	• Not yet scientifically conceivable today (eg, steel production via biological means) • Unlikely to have material economic impact by 2050 (eg, biology-based parallel computing)
Domains Cluster of sectors	• Direct biology-centric domains where core product or service could be inherently biological, such as the following sectors: healthcare systems and services, pharmaceuticals and medical products, agriculture, consumer goods and services, basic materials manufacturing, and energy	• Other sectors not inherently biological that experience indirect impact (eg, upstream, downstream, ancillary), including insurance, entertainment, finance
Impact Value gain drivers	• Value gain drivers of direct impact estimated – Reduced disease burden translated to economic productivity – Improved quality, measured by greater willingness to pay – Cost productivity (eg, incremental cost saving to produce product) – Environmental benefit (from reduced greenhouse gas emissions)	• Knock-on effects, such as reduced agricultural land use from shifting to alternative proteins or changes to life insurance from longer life spans • Broader societal impact, such as effects on inequality or population phenotype

Source: McKinsey Global Institute analysis

2) 4 arenas

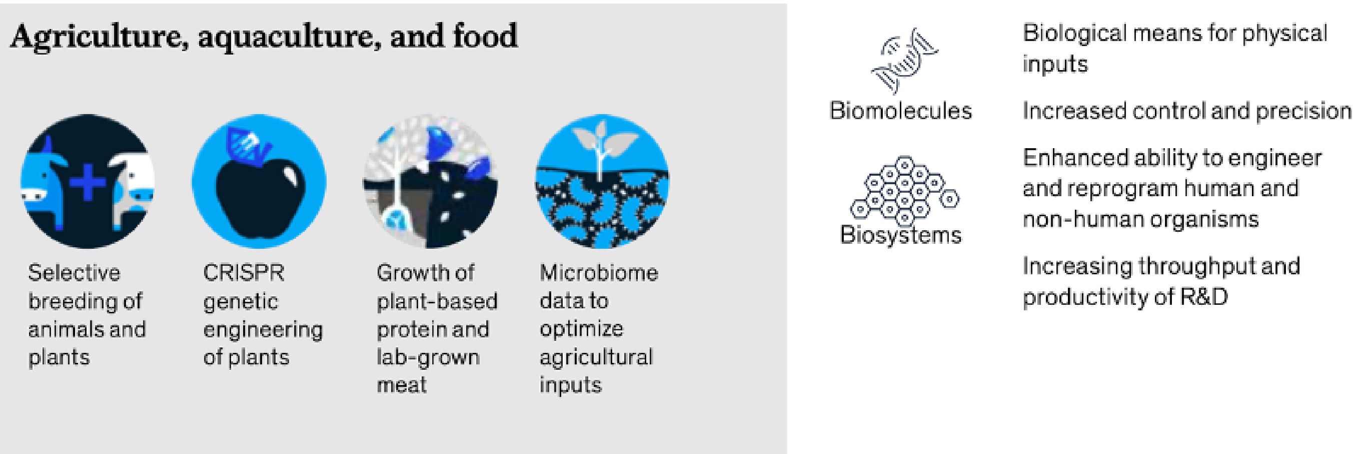
There are innovations happening in 4 main arenas: biomolecules (mapping, measuring and engineering of molecules), biosystems (engineering of cells), biomachines (interface between biology & machines), biocomputing (use of cells/molecules such as DNA for computation)

Bio innovation is occurring in four key arenas.

	Biomolecules	Biosystems	Biomachine interfaces	Biocomputing
Definitions				
Mapping	Cellular processes and functions via measuring intracellular molecules (eg, DNA, RNA, proteins) in the study of omics	Complex biological organizations and processes, and interactions between cells	The structure and function of nervous systems of living organisms	Intracellular pathways or networks of cells to return outputs based on specific conditions (for computation)
Engineering[1]	Intracellular molecules (eg, via genome editing)	Cells, tissues, and organs, including stem cell technologies and transplantation	Hybrid systems that connect nervous systems of living organisms to machines	Cells and cellular components for computational processes (storing, retrieving, processing data)
Examples	Gene therapy for monogenic diseases	Cultured meat grown in a lab	Neuroprosthetics for motor control (implant or external headset) of human or robotic limb	Data storage in strands of DNA

1. Design, de novo synthesis, or modification.
Source: McKinsey Global Institute analysis

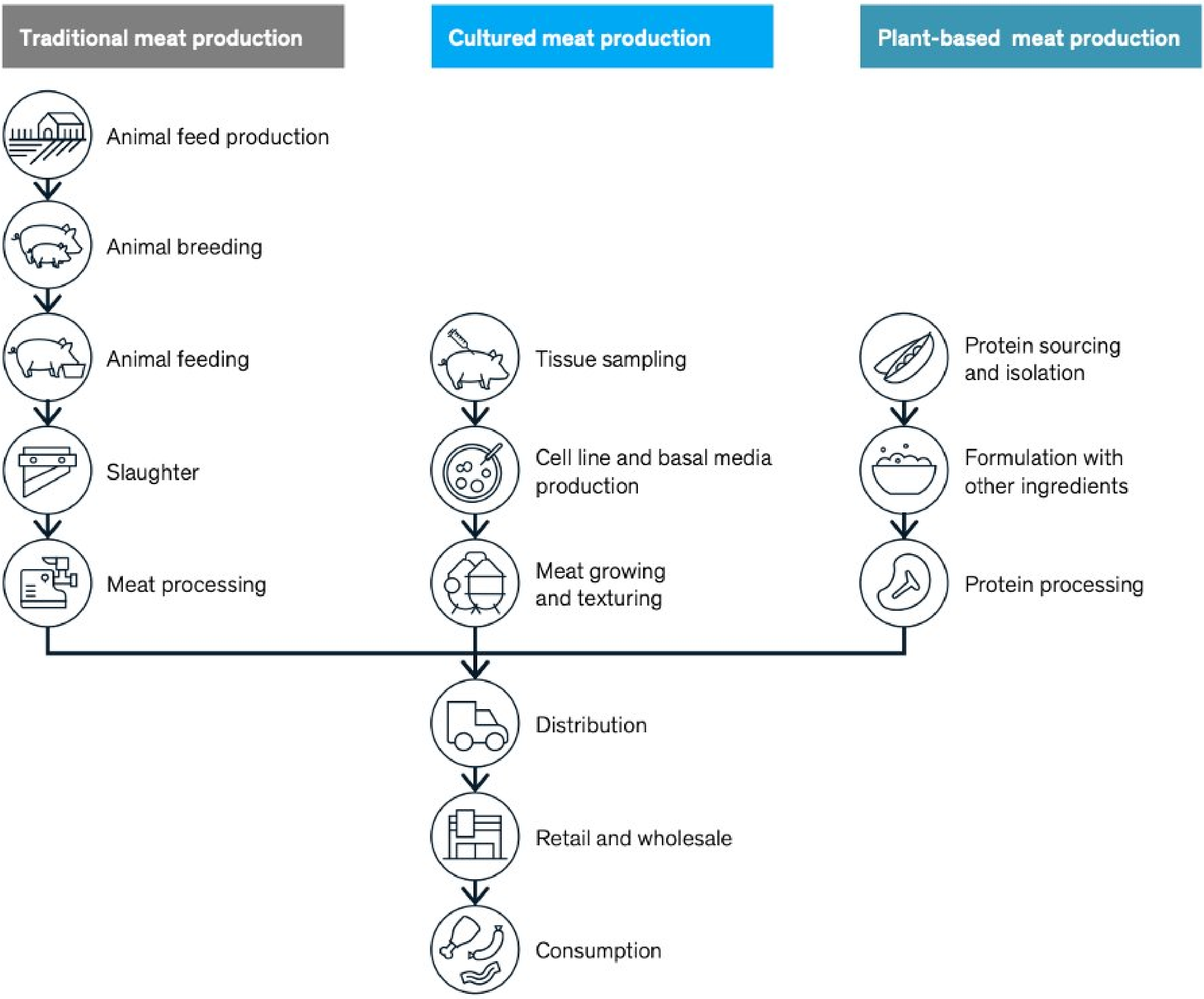
3) Agriculture
The human population is growing quickly and providing food for everyone might be one of the greatest challenges that humans face. Biotech is responsible for many innovations in this field, and we will talk about the two stages of genetically modified food.



The first wave of genetically engineered crops (GMOs) are organisms with foreign genetic material. After the emergence of CRISPR highly specific cisgenic changes and intragenic changes are possible. Crops can be engineered to be tastier and more heat-resistant which will be more

The meat value chain is shifting.

Traditional meat production vs cultured meat and plant-based meat production



Source: McKinsey Global Institute analysis

important with increasing climate change. Today genetically modified crops make up about 12% of cropland. Furthermore, the US FDA has declared that it will not regulate the plants if editing does not lead to foreign DNA. Other innovations include e.g. lab-based food

which is significantly more sustainable than traditional food. The direct annual impact of biology in this sector is expected to be $800b-$1.2t over the next 10-20 years. Acceptance of consumers will be key to the success of genetically modified food.

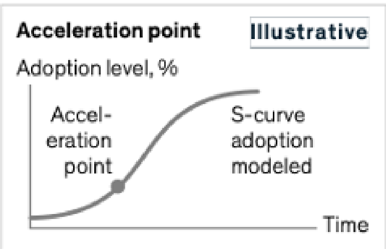
For applications in agriculture, aquaculture, and food, timing of adoption varies.

Example use cases

Not exhaustive

Estimated time horizon of acceleration point of use cases in agriculture, aquaculture, and food
The acceleration point is when adoption starts to experience rapid growth[1]

Existing Before 2020	**Short term** 2020–30	**Medium term** 2030–40	**Long term** Beyond 2040
Marker-assisted breeding (crops)	Crop microbiome diagnostics and probiotic treatments	Genetically engineered crops and animals used for food—extended shelf life of food products	Genetically engineered crops—enhanced photosynthesis
Marker-assisted breeding (animals used for food)	Soil microbiome diagnostics and microbial seed treatments	Genetically engineered crops and animals used for food—disease resistance/control	
Genetic tracing of food origin, safety, and authenticity (eg, allergens, species, pathogens)	Water microbiome diagnostics and microbial water treatments (eg, microalgae-based oral vaccine for aquaculture)	Genetically engineered crops and animals used for food—higher nutritional contents, better taste, specific shapes	
Genetically engineered crops—resistance to droughts	Genetically engineered crops—improved input efficiency (eg, irrigation water use)	Cultured meat	
	Plant-based proteins (eg, meat, dairy, eggs)	Genetically engineered animals used for food—faster growth	
		Genetically engineered animals used for food—reduced greenhouse gas emissions	

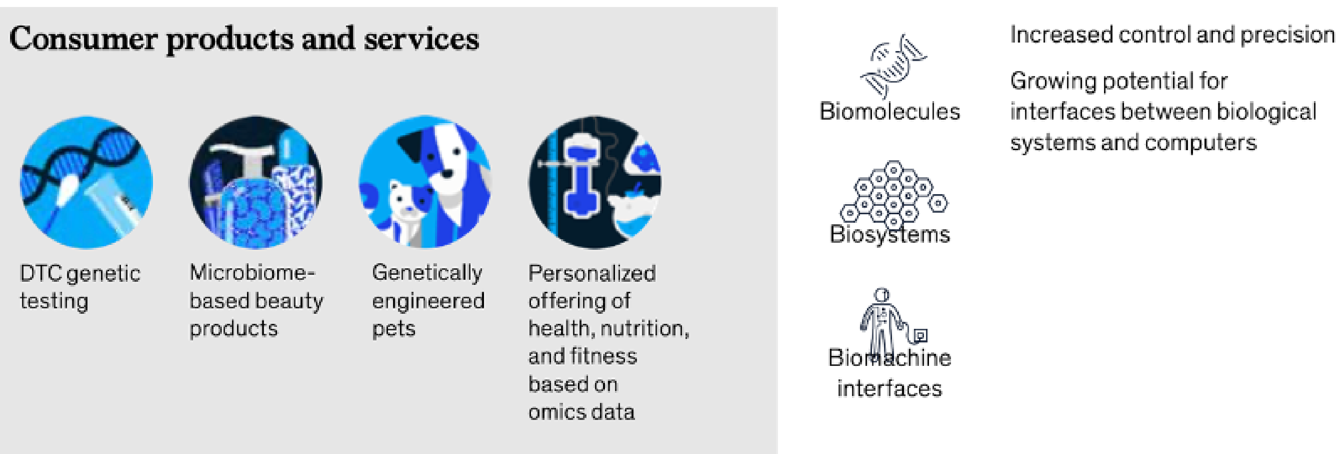


1. The point at which adoption accelerates. We characterize this as the max of the second derivative of the adoption curve—see our technical appendix for more detail. Adoption level and timing for each use case depend on many variables, including commercial availability, regulation, and public acceptance. These estimates are not fully risk- or probability-adjusted.

Source: McKinsey Global Institute analysis

3) Consumer products and services

The availability of biological data opens the opportunity to personalize products and services based on the DNA of the customer.



Some potential application areas are in healthcare, beauty products based on microbiomes, and innovative approachesto wellness and fitness. Companies can now analyze the DNA and design a product/service that perfectly fits the customer's needs.

This will play a big role in professional sports as every competitive advantage that can be created is important in this field. The expected annual impact is $200bn-$800bn.

For applications in consumer products and services, timing of adoption varies.

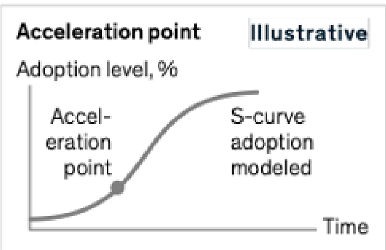
Example use cases

Not exhaustive

Estimated time horizon of acceleration point of use cases in consumer products and services

The acceleration point is when adoption starts to experience rapid growth[1]

Existing Before 2020	**Short term** 2020–30	**Medium term** 2030–40	**Long term** Beyond 2040
DTC genetic testing—ancestry	DTC genetic testing—personal insights about health and lifestyle	Microbial teeth whitening products	Gene therapy—enhanced athleticism
	Personalized dating services based on genetic profile	Biosensors for monitoring of personal health, nutrition, and fitness based on omics data	Gene therapy—hair loss
	Personalized meal services based on genetic and microbiome profile		Gene therapy—skin aging
	Personalized probiotics and vitamins based on genetic and microbiome profile		
	Pet genetic testing (eg, breed) and gene therapies		
	Pet microbiome testing and microbial treatments (eg, fecal transplant)		
	Genetically engineered pets		
	Microbial skin care products		



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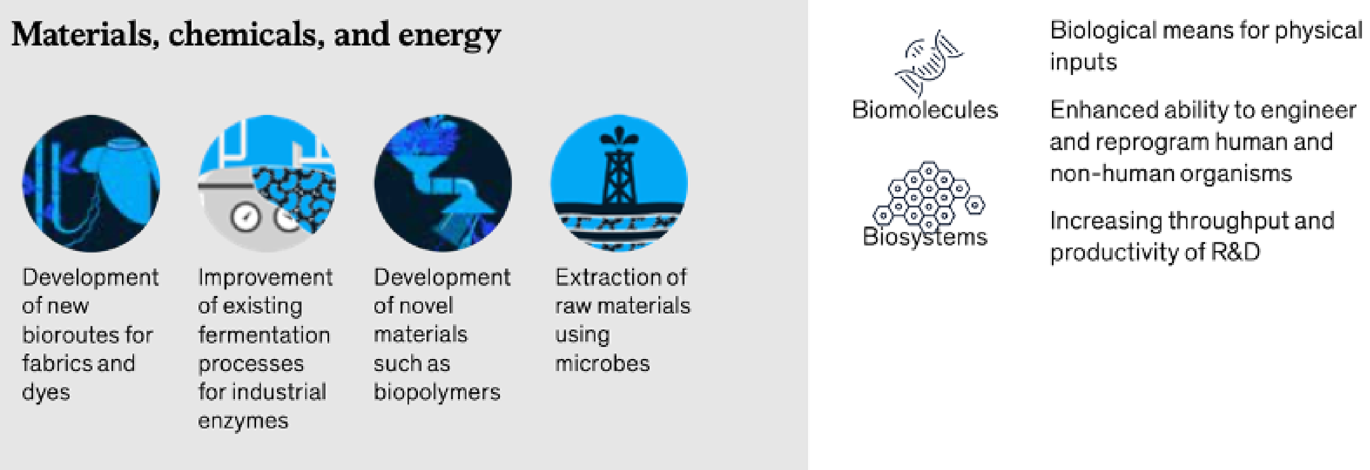
Source: McKinsey Global Institute analysis

4) Production and energy

Improved fermentation processes increase the speed of production and/or quality of materials. Furthermore, there is progress in the energy sector with greater use of biofuels and improving energy extraction and storage.



5) Effects that aren't even included

The impact of applications could have knock-on effects on the broader economy. One example is that more healthy lab-based food leads to improved health which leads to people living longer which leads to more demand for eldercare.

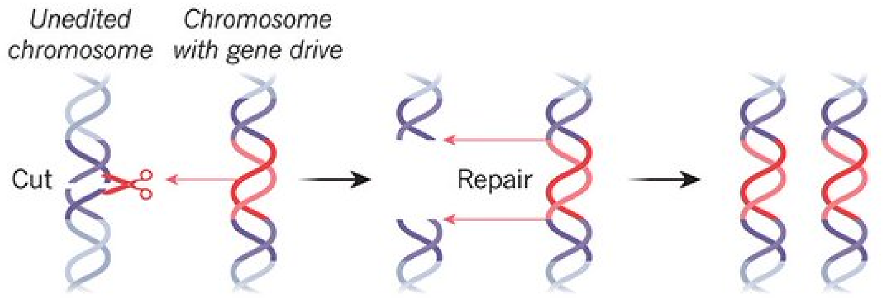
6) Important risks

Biology is self-replicating, self-sustaining, and doesn’t know jurisdictional boundaries. Furthermore, genetically engineered gene drives might have great health benefits but are hard to control and could also dramatically damage ecosystems.

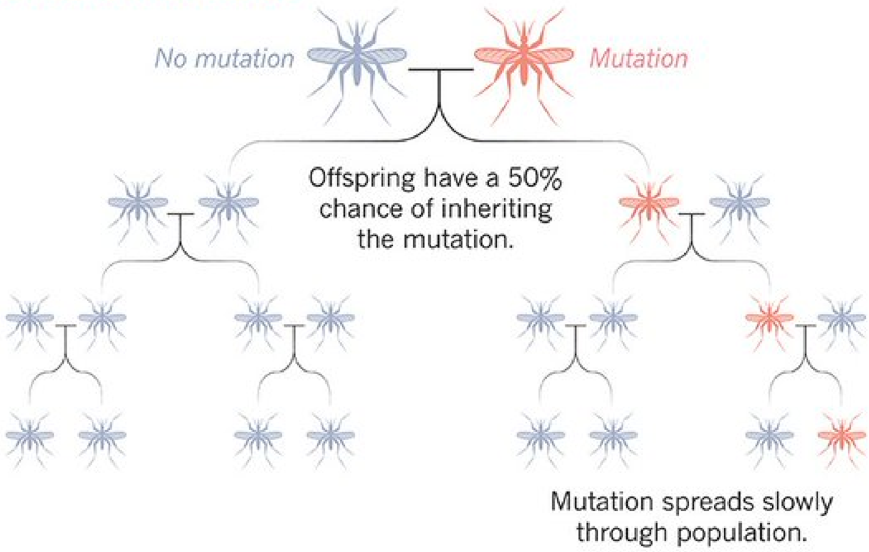
How gene drives work

Gene drives use CRISPR to insert and spread a genetic modification through a population at higher than normal rates of inheritance. Researchers plan to use drives to eradicate malaria-carrying mosquitoes and other pests.

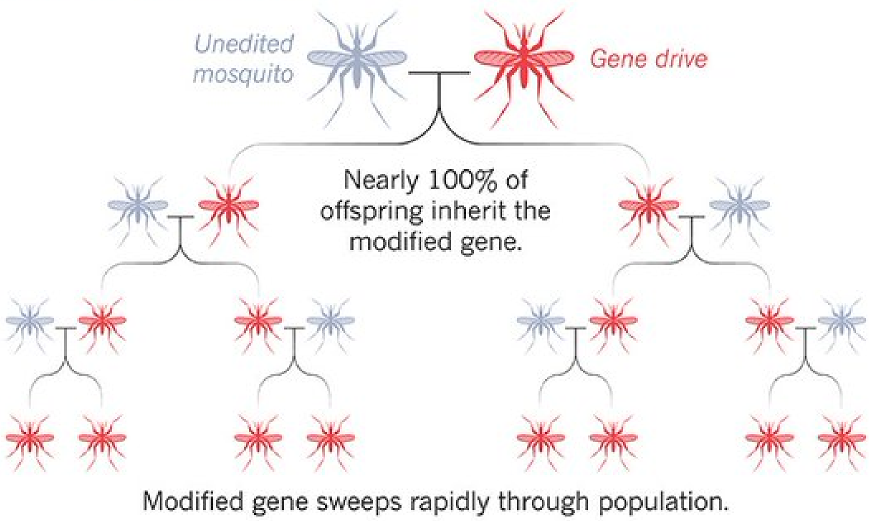
Once a gene drive is engineered into an animal's genome, the animal's offspring will inherit the drive on one chromosome and a normal gene from its other parent. During early development, the CRISPR portion of the drive cuts the other copy. The cut is then repaired using the drive as a template, leaving the offspring with two copies of the modification.



Standard inheritance



Gene-drive inheritance



Most different sectors in biology are highly interconnected and changes in one part of the system influence all parts and could have unintended consequences. The entry costs are very low which could lead to misuse - bioweapons and biohackers are impossible to control and kits

to perform CRISPR gene editing are sold on the internet and accessible to everyone.
Different value systems and moral understanding make it hard to form a consensus on where the barriers and limits should be.

Important ethical questions are arising as well (e.g. editing out disabilities before birth or choosing baby's skin color). Moreover, unequal access could lead to socioeconomic disparity and discrimination which would lead to a lower acceptance rate in society.

Regulations will be important to ensure safety but monitoring developments in science and adjusting regulations accordingly are even more important. National regulations won't be sufficient as biology doesn't know borders (as we all experience during COVID).

One of the main problems is that most regulators aren't scientists and aren't able to adjust regulations accordingly to the latest developments. There are serious privacy concerns as well as the data collected comes directly from the DNA and couldn't be more personal.

7) Commercialization
Once the stage of scientific research is finished, commercialization and diffusion can begin. 4 factors that determine the journey from lab to market and ultimately the success:

Six factors affect the pace and extent at which bio innovations are adopted.

Stages of adoption and milestones

Not exhaustive

	Scientific feasibility: Experimental success in target population	Commercial availability: First commercial offering
Scientific research From ideas to innovation	**Commercialization** From lab to market	**Diffusion** Spread across population
1. Research investments	**2. Value proposition**	
Funding. Scientific research requires considerable investment Talent. Maintaining a cadre of highly talented scientists is critical to sustaining the vitality of research Tools. The development of new tools and technologies in biological sciences extends research capabilities Access to data. The emergence of annotated and accessible scientific databases is pivotal to the development of accessible knowledge	Compelling value propositions offered to initial adopters including increased utility such as improved quality or addressing unmet need	Continuous improvement of value proposition including increased utility, meeting unmet need, and cost competitiveness with existing offerings
	3. Business models	
	New business models may be needed to achieve positive margins; companies experiment with customer segmentation, customer acquisition costs, and pricing, for instance	Continuous improvement of business models
	4. Go to market	
	New offering launched to reach the right audience; elements include product positioning and marketing to educate potential customers	Continuous optimization of marketing and sales strategies including marketing mix and sales channels
	5. Operational scalability	
	Ability to scale for initial adoption, including skills, infrastructure, processes, and supply chains	Continuous improvement of ability to scale including skills, infrastructure, processes, and supply chains
6. Risk and mechanisms for governing use		
Science cannot be pursued in a vacuum, but needs to take account of broader benefits and risks	Societal acceptance and initial regulatory go-ahead where applicable	Societal acceptance combined with ongoing regulatory review and approval; includes post-market surveillance and approval to enter new markets

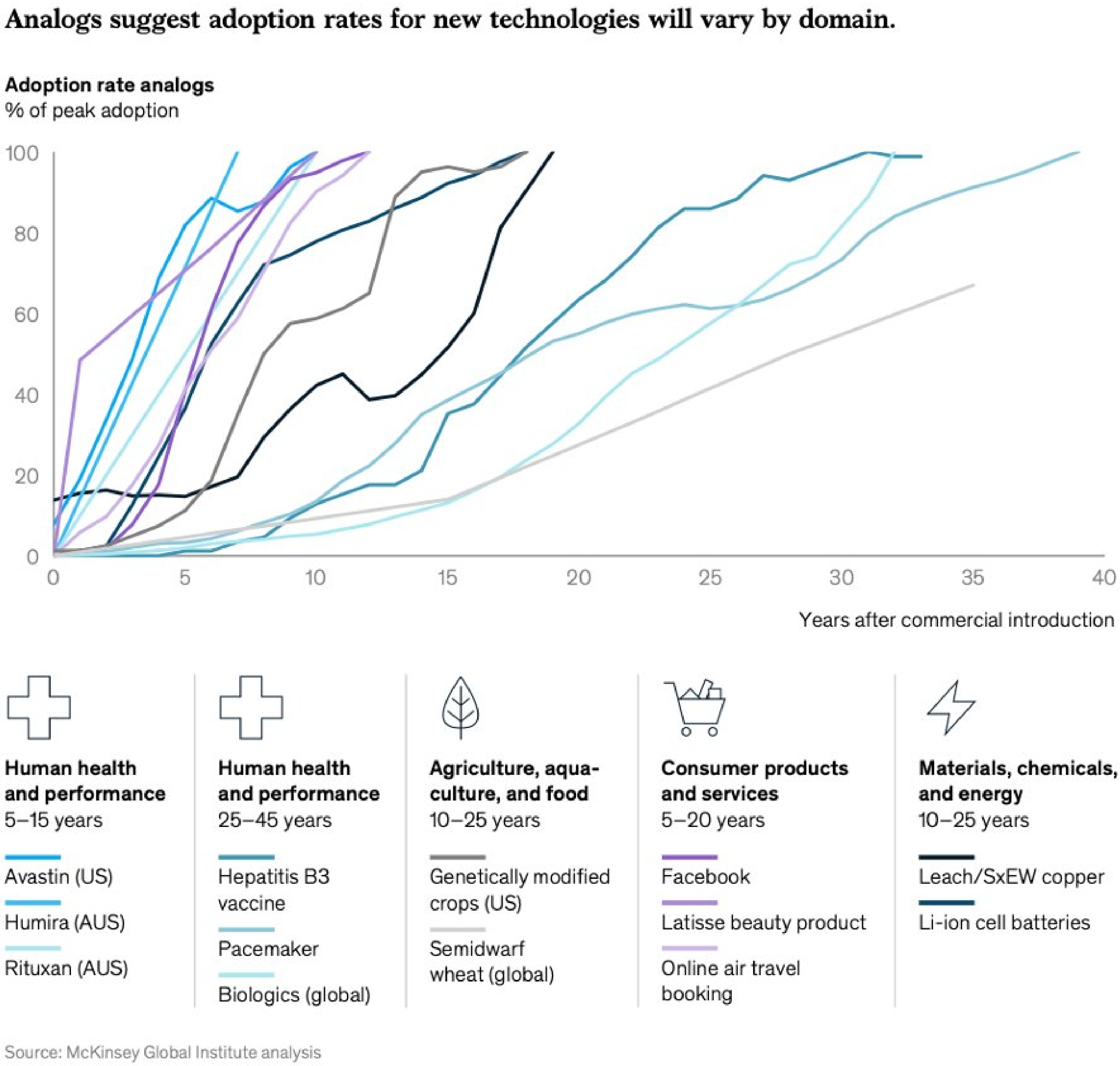
a) Does the product/service offer a value proposition to end-users?

- products compete on price and quality

b) Is the business model suitable in a fast-changing landscape?
- Biotech is driven by innovation and companies must be able to adapt to new technologies quickly

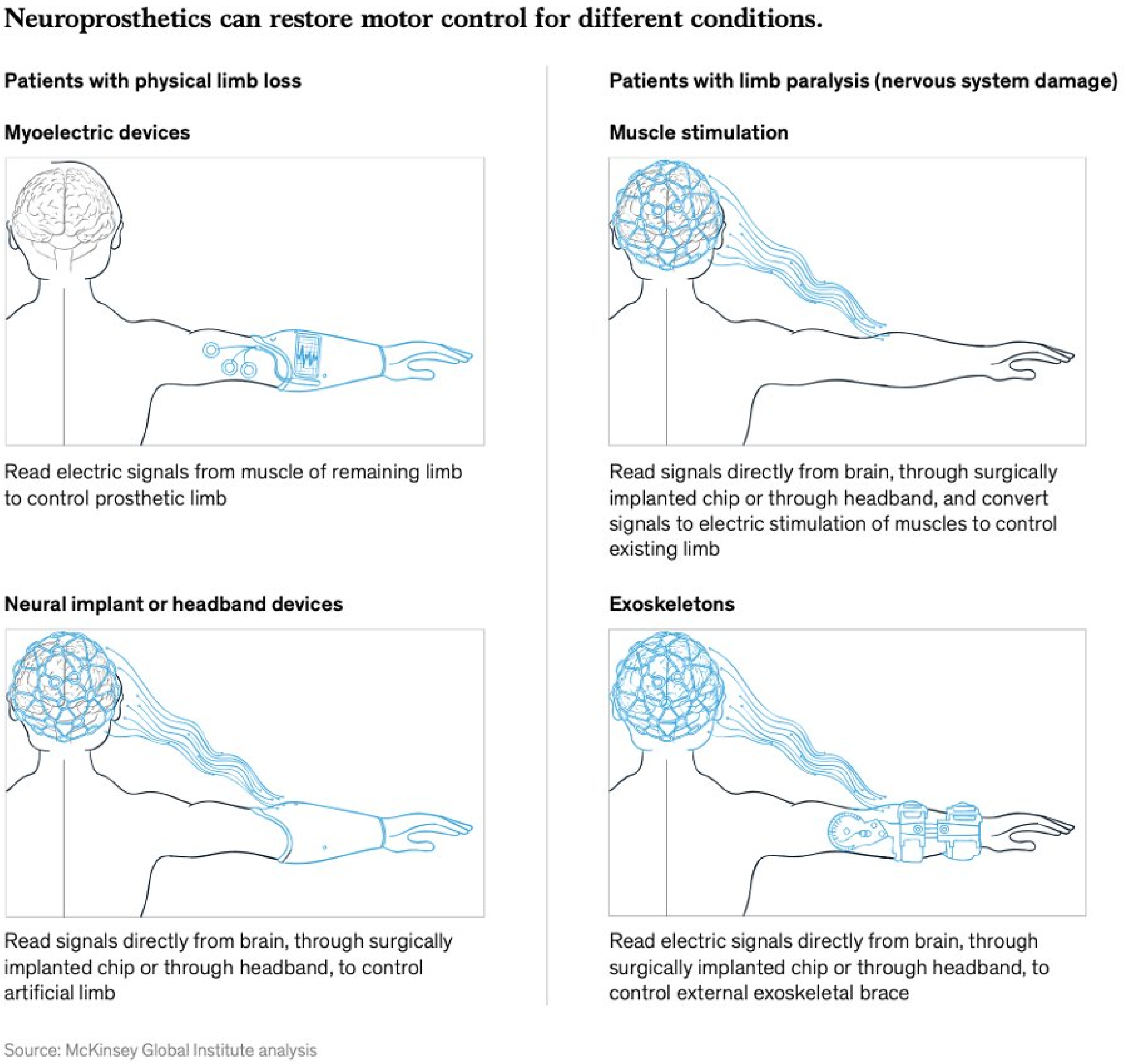
c) Ensuring new products/services get to the right potential customers
- important to define the target group and reach them efficiently
d) Ability to scale up operations
- companies need the right infrastructure, knowledge & supply chain

8) Adoption rate
The adoption rate is expected to vary between different sectors. Human health is expected to have the highest rate of adoption as it directly improves the quality and length of lives.



9) Neuroprosthetics
Neuroprosthetics connect the human nervous system to computers and furthermore not only providing control of prosthetic

limbs but also restoring lost sensory function.



Would highly appreciate thoughts/feedback/opinions :)
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