# Twitter Thread by Alessandro



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**- Thread The Bio Revolution -**

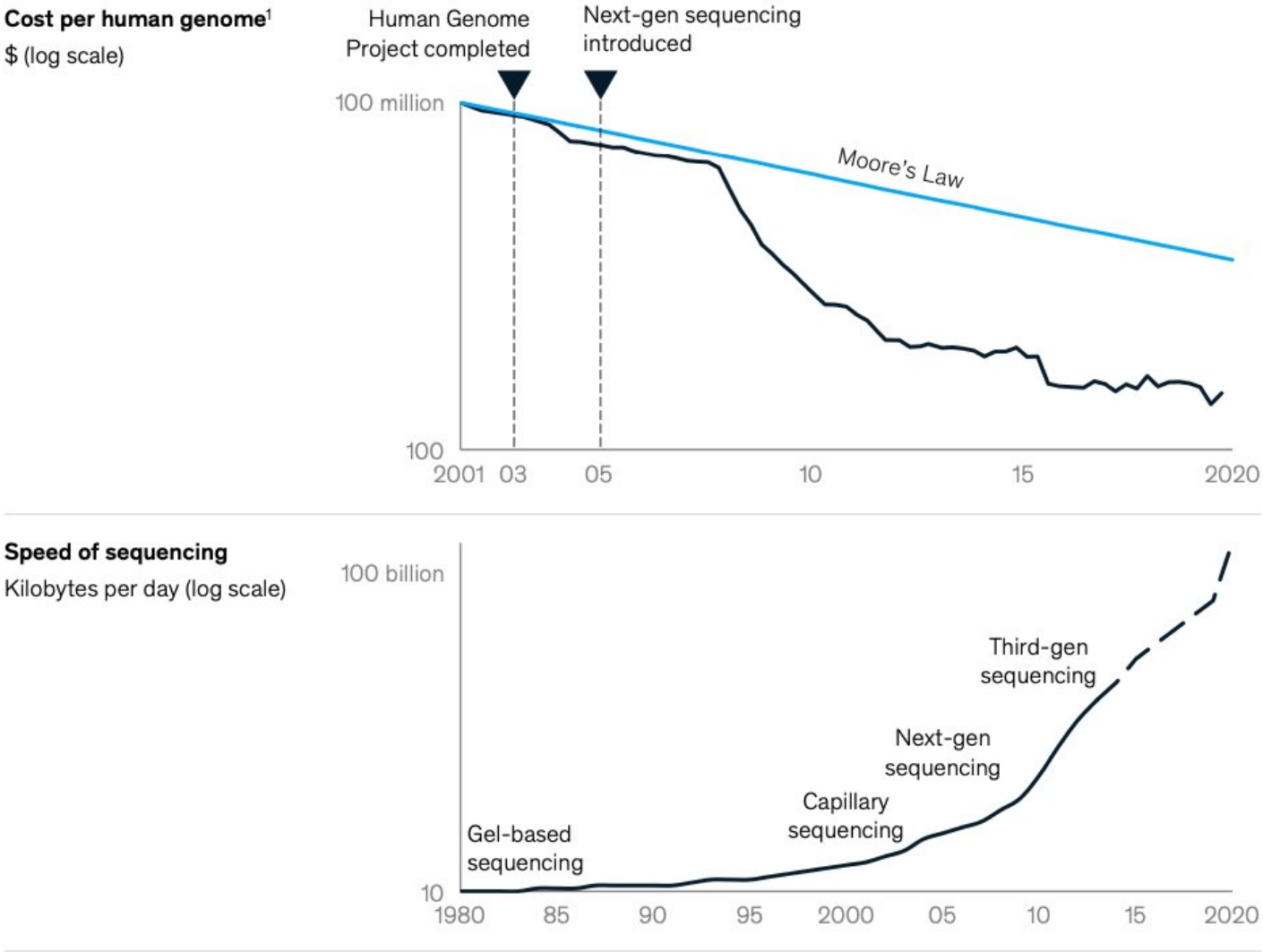
**McKinsey published a 200-pages report on the impact of biotech in May earlier this year and I want to summarize the most important points for you today.**
**Feel free to reach out and I will send you the whole report.**



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.

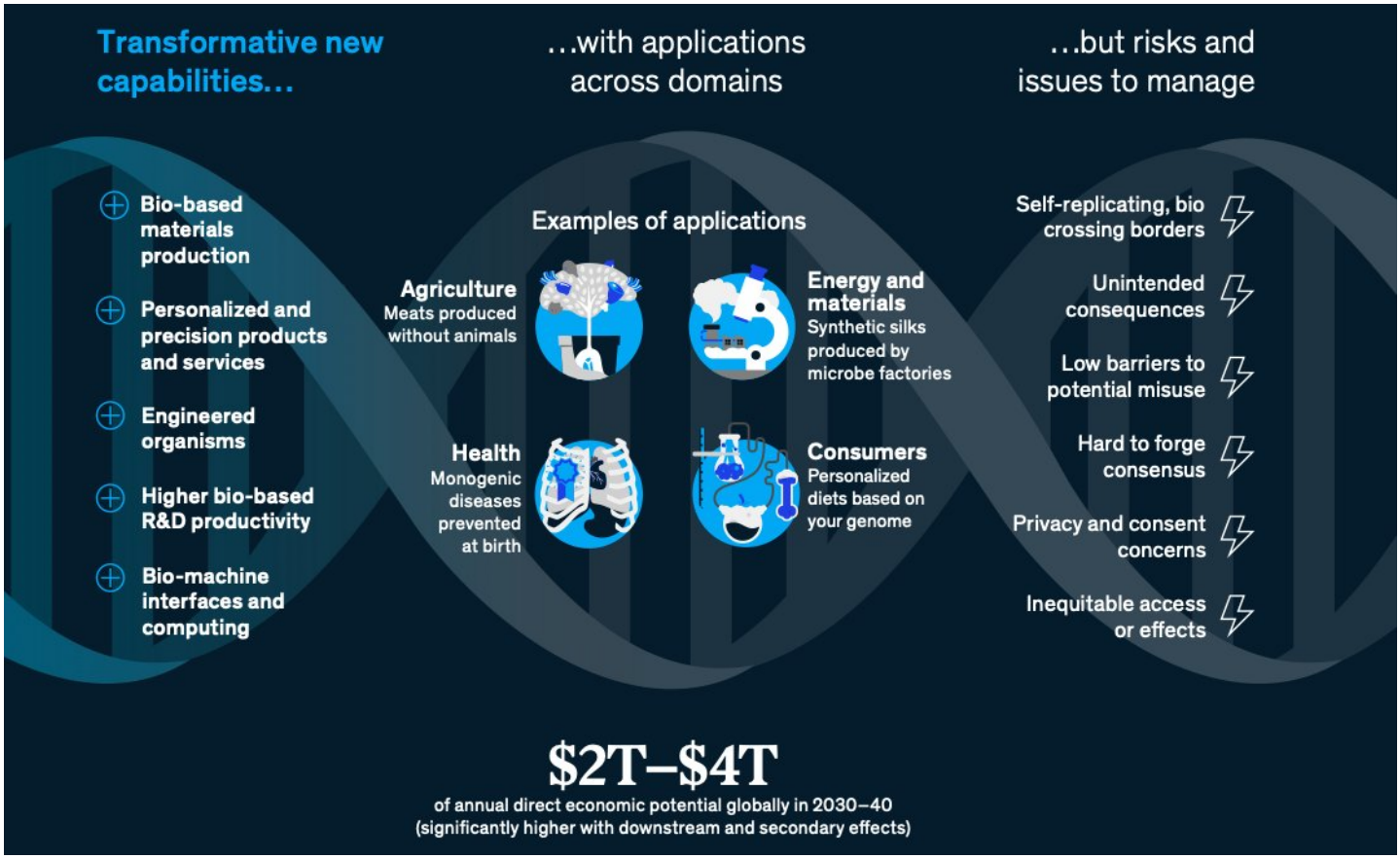
**Rapid advances in computing, bioinformatics, and AI are enabling the analysis of omics data.**




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**<br>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**<br>Maturity of use cases | • Scientifically conceivable today and plausibly commercialized by 2050 (eg, CAR-T therapies for solid tumors)<br>• 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)<br>• Unlikely to have material economic impact by 2050 (eg, biology-based parallel computing) |
| **Domains**<br>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**<br>Value gain drivers | • Value gain drivers of direct impact estimated<br>– Reduced disease burden translated to economic productivity<br>– Improved quality, measured by greater willingness to pay<br>– Cost productivity (eg, incremental cost saving to produce product)<br>– 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<br>• 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.

**Agriculture, aquaculture, and food**


Selective breeding of animals and plants


CRISPR genetic engineering of plants


Growth of plant-based protein and lab-grown meat


Microbiome data to optimize agricultural inputs


Biomolecules


Biosystems

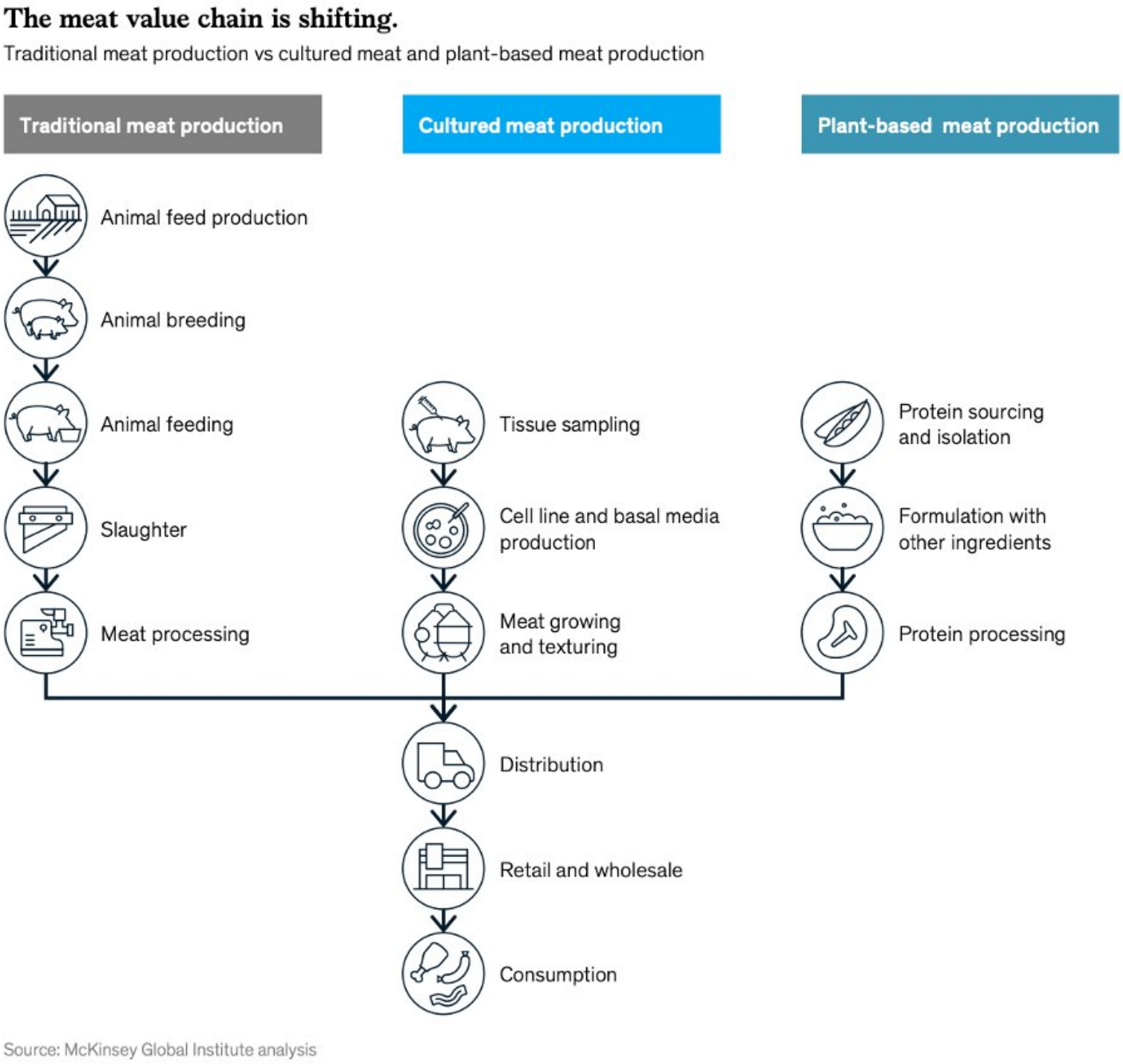
Biological means for physical inputs

Increased control and precision

Enhanced ability to engineer and reprogram human and non-human organisms

Increasing throughput and productivity of R&D

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




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.

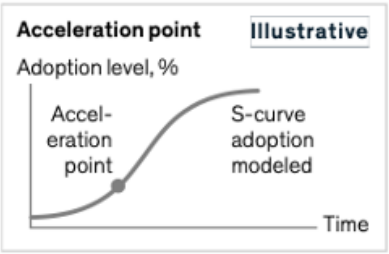
## For applications in agriculture, aquaculture, and food, timing of adoption varies.

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



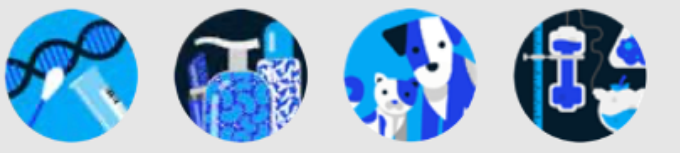

1. The point at which adoption accelerates. We characterize this as the max of the second derivative of the adoption curve—see our technical appendix for more detail. Adoption level and timing for each use case depend on many variables, including commercial availability, regulation, and public acceptance. 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.

## Consumer products and services



DTC genetic testing

Microbiome-based beauty products

Genetically engineered pets

Personalized offering of health, nutrition, and fitness based on omics data




Increased control and precision

Growing potential for interfaces between biological systems and computers

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.

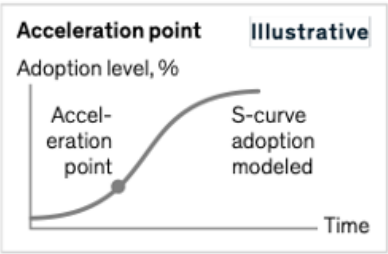
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Example use cases

Not exhaustive

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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 | | |

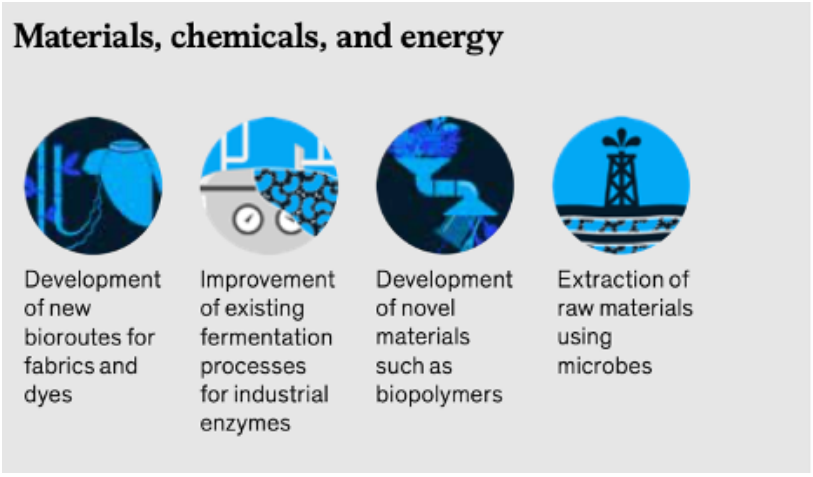



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Source: McKinsey Global Institute analysis

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.



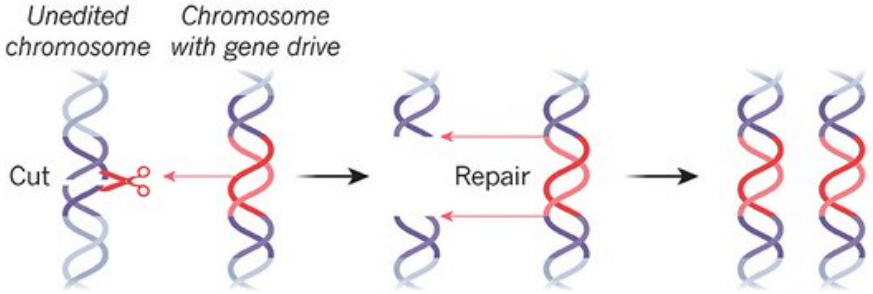
6) Important risks

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.

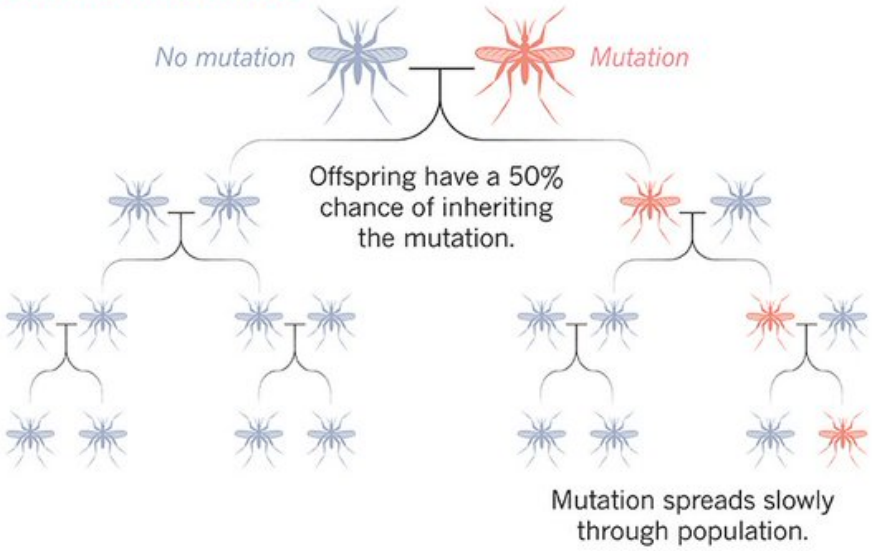
# How gene drives work

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.

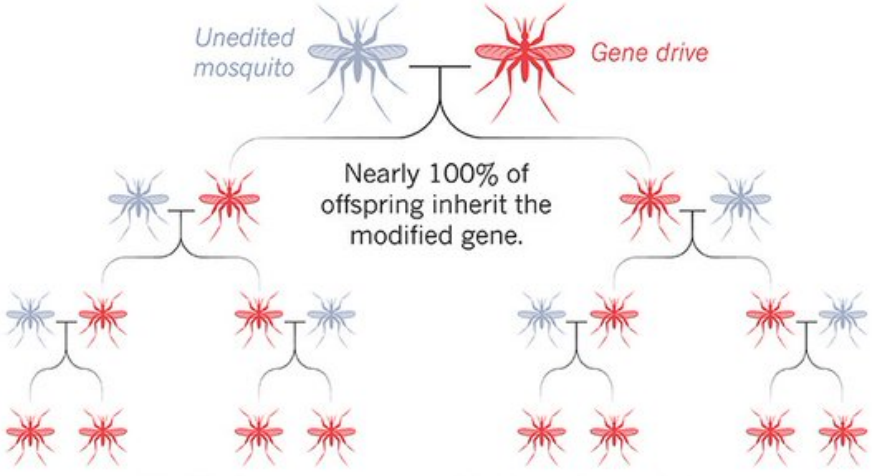
Once a gene drive is engineered into an animal's genome, the animal's offspring will inherit the drive on one chromosome and a normal gene from its other parent. During early development, the CRISPR portion of the drive cuts the other copy. The cut is then repaired using the drive as a template, leaving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




## Standard inheritance




## Gene-drive inheritance




©nature

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).

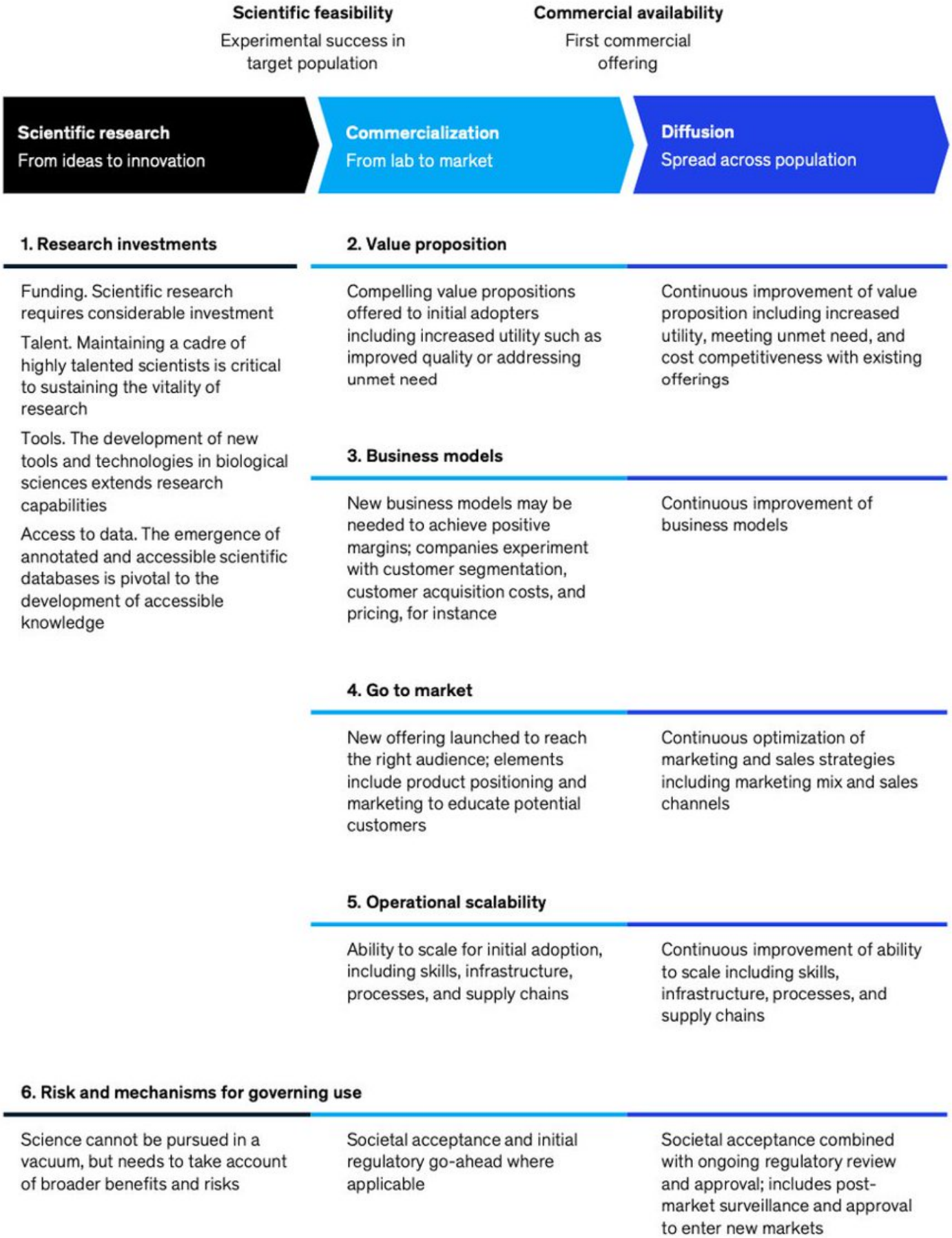
One of the main problems is that most regulators aren't scientists and aren't able to adjust regulations accordingly to the latest developments. There are serious privacy concerns as well as the data collected comes directly from the DNA and couldn't be more personal.

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




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

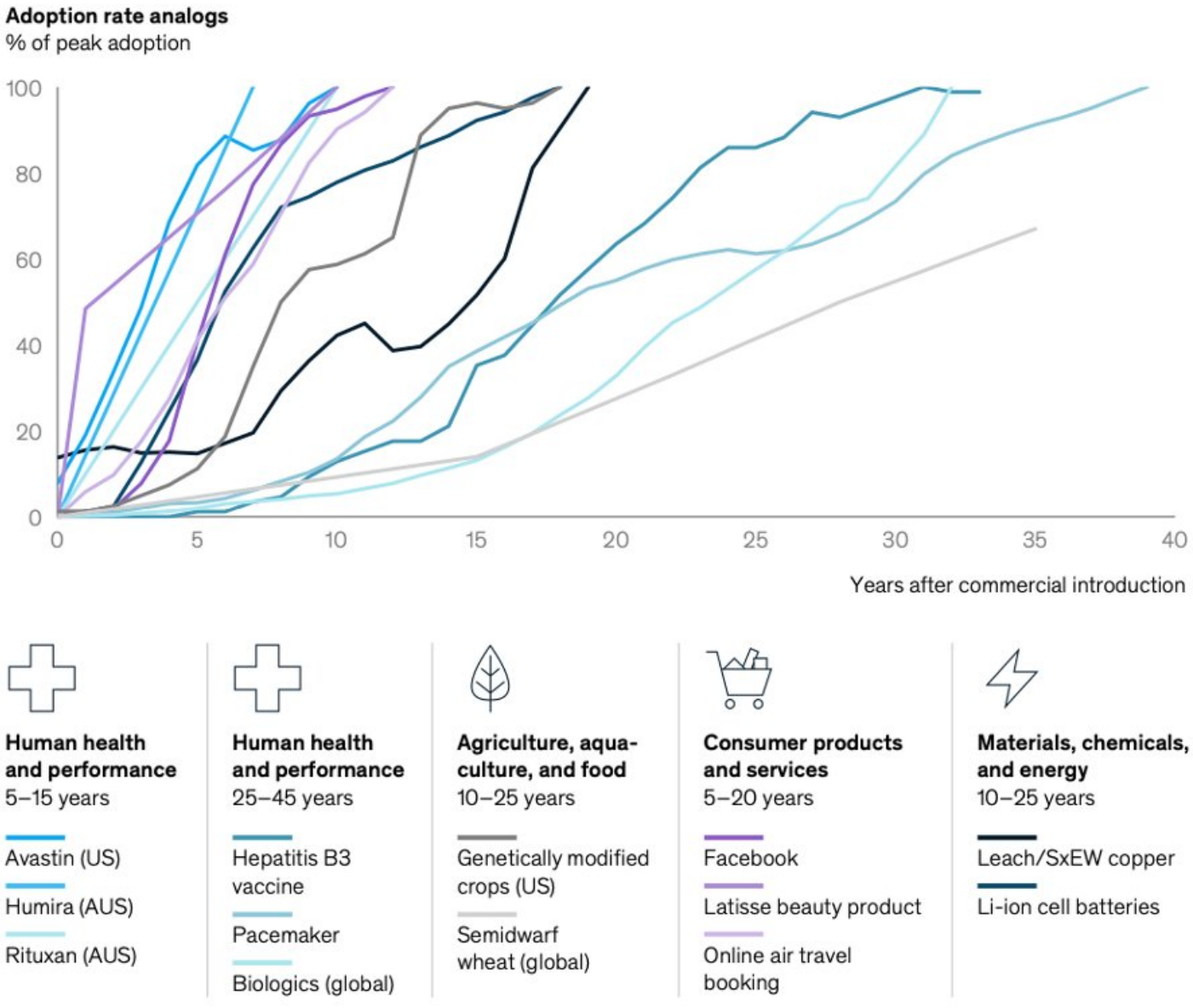
- products compete on price and quality

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.

**Analogs suggest adoption rates for new technologies will vary by domain.**




Source: McKinsey Global Institute analysis

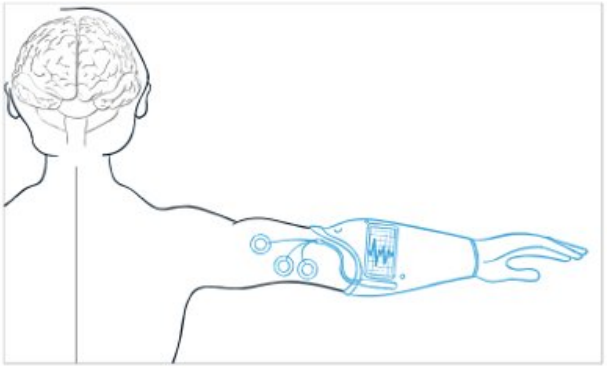
9) Neuroprosthetics
Neuroprosthetics connect the human nervous system to computers and furthermore not only providing control of prosthetic

limbs but also restoring lost sensory function.

**Neuroprosthetics can restore motor control for different conditions.**

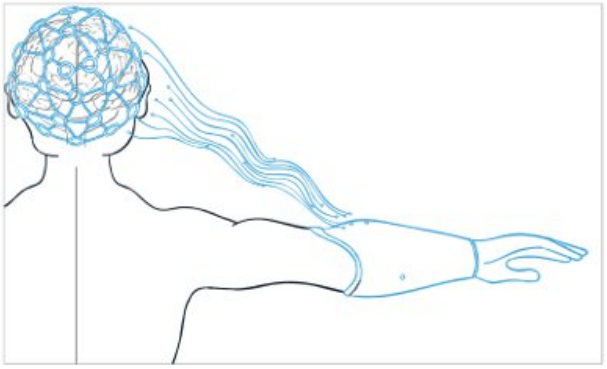
**Patients with physical limb loss**

**Myoelectric devices**



Read electric signals from muscle of remaining limb to control prosthetic limb

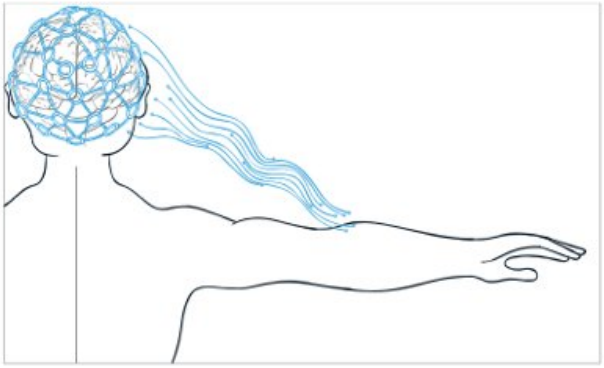
**Neural implant or headband devices**



Read signals directly from brain, through surgically implanted chip or through headband, to control artificial limb

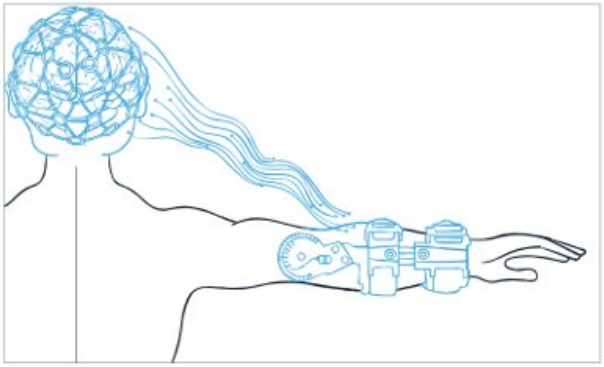
**Patients with limb paralysis (nervous system damage)**

**Muscle stimulation**



Read signals directly from brain, through surgically implanted chip or through headband, and convert signals to electric stimulation of muscles to control existing limb

**Exoskeletons**



Read electric signals directly from brain, through surgically implanted chip or through headband, to control external exoskeletal brace

Source: McKinsey Global Institute analysis

Would highly appreciate thoughts/feedback/opinions :)
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