The slide features two large, thick black L-shaped brackets. One is positioned in the top-left corner, and the other is in the bottom-right corner, framing the central text.

ETHICS OF GENOME EDITING

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EGE

Over 2 years ago the Commission requested the EGE to produce an Opinion on the ethics of genome editing.

It is hoped to publish the opinion before the end of this year.

This presentation, therefore, is my own interpretation of that which we have spent a great deal of time discussing.

We were asked to look at the use of genome editing in

- **Humans – both somatic and heritable**
- **Animals – especially non-human primates**
- **Plants**
- **Gene drive applications**



The possibility of intervening in the genome in order to change the molecular structure or the function of a gene has reached new dimensions with the discovery of technologies which can change genetic and epigenetic features in an unprecedentedly targeted way. These rapidly evolving technologies can in principle be applied to every living organism – be it a microorganism, a plant, an animal or a human being. There are several aspects which fundamentally distinguish the new technologies from those that were previously available to change a gene.

There have been many reports on the use of genome editing, primarily referencing its use in humans, since the use of CRISPR/Cas9 was identified as a (relatively) precise tool for removing, adding or altering parts of the genome.

The EGE Opinion will not attempt a scientific account or even a comprehensive ethical analysis. It is our role to consider how the European Union can and should shape governance and policies for the profound possibilities that all new technologies that enable the editing of organism's genomes provide.

There are a number of 'issues' which are to be considered prior to looking at specific applications:

1. Humanness and humanisation

- What distinguishes humans from other forms of life – intelligence, sentience?
- What are the responsibilities with regard to others?
- Does our genome determine who we are?
- Can other organisms be 'humanised'? If so, what are the limits we might impose, what obligations result and what are the rights of the 'humanised' organism? (This has important implications for xenobiology, and the way the new techniques are to be used on non-human primates)

2. Diversity

- How do we protect the richness and variety of organisms. The technology may be neutral in this area, but its application may not be. Care needs to be taken to assure retention of diversity – within human populations and within agriculture in particular.
- For example, Gene editing could be used to preserve corals and their ecosystems, to diversify agriculture to shore up food security, to combat invasive species plaguing ecosystems around the world, and even to resurrect extinct species.

3. Safety

- There is much debate as to whether to use the technology when we are not sure of its safety; particularly in humans and animals.
- All technologies applied to living systems have an element of risk. Should we weigh the risks against benefits. If so, can we measure benefit in the same frame as risk?
- What could we mean by 'safe enough'? Is the application of the technology at least as safe as that which is currently available?
- Should a new technology be used where 'adequate' technologies already exist.

4. Governance

- Genome editing is already being used in many contexts. Who should decide what is done? What are the criteria for making decisions? Should the public be involved in decisions as to the contexts in which the technology is applied?

- I choose to consider plants first, for they are the area in which much of the work is already being done and commercialised.
- We use plants for many purposes, especially for food, feed, fibre, fuel and even as factories for producing chemicals to replace fossil fuels
- The science provides almost unlimited power to modify this environment – the economic impact of choosing to use or not to use plants produced using any new technology (especially genome editing) is likely to be significant. What is the difference (other than ease of production) between genome edited plants and genetically modified plants?
- New varieties of plants are continuously being created that are better suited to local conditions or have desired characteristics including consumer choice, shelf-life, defeating pests or weeds.... Precaution dictates that case-by-case consideration of the products of gene modification and of their use in particular environments is required. **Should this analysis identify both risk and benefit to humans and the environment?**



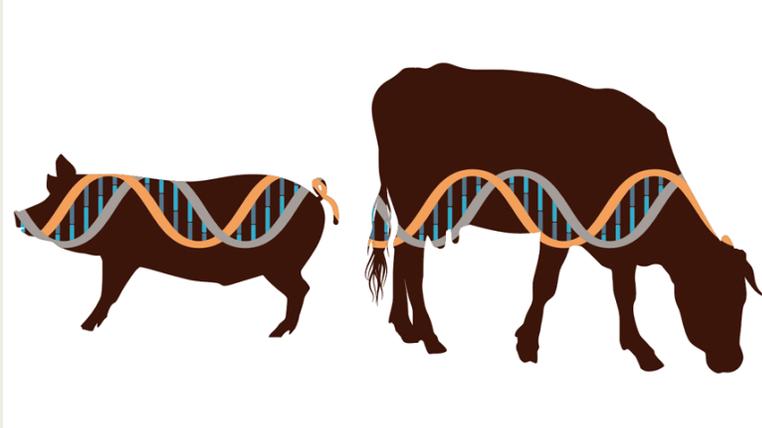
Plants

- What therefore constitutes safe? Is a new variety to be tested on the basis of ‘as safe as that currently on the market’? Does the new variety have to be safer than that currently used? Should the whole system, including chemicals used, land used and protection (or otherwise) of the agricultural diversity be taken into account in deciding on safety? Should the requirement “based on an examination of the potential benefits and costs of action or lack of action (including, where appropriate and feasible, an economic cost/benefit analysis)” be part of this analysis?
- Could a system for traceability be instituted? If not, how can the perceived concerns of the European consumer be addressed. How would such traceability criteria work given that the products are grown throughout the world, and if not regulated in one jurisdiction, may be used as the starting material for a host of new varieties?
- Should companies introducing new varieties, regardless of method of the provenance, be required to identify the impact of their use on biodiversity and the environment?
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- Should consideration could be given to structures that support smaller actors to undertake risk assessments and enter the market?
- **There is a need to ensure food security, provide renewable resources for fuel, feed and fibre, and ensure the retention of biodiversity and protect our environment. Gene-editing technologies could, with appropriate and proportionate control enhance our ability to achieve these goals.**

Animals

Consideration of animals has been in 4 parts-

- a) Research
- b) Developed for xenotransplantation
- c) produced for commerce: livestock breeding
- d) Modification of non-human primates



The animal genome has been manipulated by humans, directly or by breeding, a very long time, but CRISPR/ Cas9, in particular, has created a new impetus for using animal models for different purposes

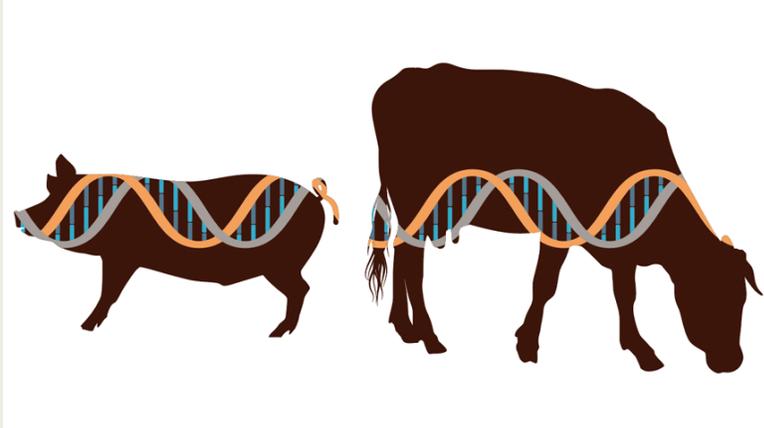
Research:

- Ethically bound to seek ways of implementing the 3Rs replacement, refinement and reduction
- Animals are used in basic research to better understand biology
- Animal models as a pre-requisite for human applications

Xenotransplantation

- Because of organ donor shortage, transplantation of organs from animals to humans has been considered for a long time

Animals



- In what way, is animal welfare fostered or hampered by genome editing and what criteria relating to its application can be applied?
- Does gene editing affect the implementation of the 3Rs and the balance among the three principles?
- What are the implications and limits of humanization? (relevant issues include xenotransplantation, research in Non human primates, hybrids, ownership and patenting)
- In agriculture and farming, animal welfare is a key concern; is genome editing a technique to increase both welfare and efficiency?
- What are the implications of genome editing for biodiversity?