Al-Farabi Kazakh National University (KazNU)

Faculty of Biology and Biotechnology

DISCIPLINE: «Modern Problems of Plant Genetics»

Lecture 1

Modern problems of plant genetics.

Amirova Aigul Kuzembayevna

Associate Professor
Candidate of Biological Science

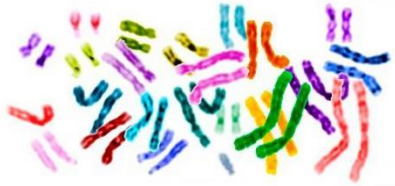
***Purpose of the lesson*:**
Acquaintance with the modern problems of biology and plant genetics.

Plan of the lesson:

1. **Modern problems in biology**
2. **Modern problems of plant genetics.**

- **Control questions:**

- What are the modern problems in biology?
- What are the modern problems in plant genetics?

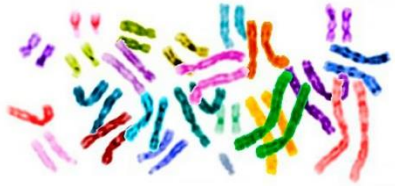


- **MODERN PROBLEMS OF BIOLOGY**

- **MODERN PROBLEMS OF BIOLOGY**

- **Taken as a whole, biology as a science is interested in three main problems:**
- **1) mechanisms of the origin of life (there is no single concept);**
- **2) variability (there is no single view of its mechanisms);**
- **3) evolution (the role of the mechanisms of variability in the evolutionary process).**

- **Everything else is covered by these three global problems, and whatever is explored will be the answer to the above questions.**



- **PROBLEMS OF MODERN BIOLOGY**

- **If we consider in more detail, then the main problems of modern biology are:**
- **1) The structure and functions of macromolecules.**

It is known that biologically important macromolecules have a polymeric structure (they consist of many homogeneous units, which, however, are not the same). Proteins are formed by 20 types of essential amino acids, nucleic acids contain four types of nucleotides, polysaccharides - a complex of monosaccharides.

In the future, one of the key problems of modern biology is the study of the structure of macromolecules and the elucidation of its influence on their complex diverse functions.

- **PROBLEMS OF MODERN BIOLOGY**

- **2) Regulation of cell functions (the mechanism of turning on genes at the molecular level; regulation of processes in cells, tissues and organs in order to maintain the relative stability of the system even under changing environmental conditions).**

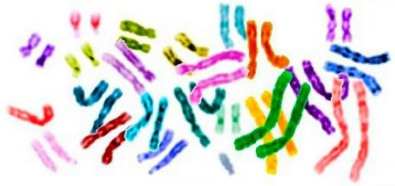
- **Regulation of intracellular processes can be achieved by changing the set and intensity of synthesis of structural and enzymatic proteins, by influencing their enzymatic activity, and by changing the rate of transport of substances through the cell membrane and other biological membranes.**
- **In the first place for study in molecular biology is the molecular mechanism of turning on genes (especially in multicellular organisms).**

- **PROBLEMS OF MODERN BIOLOGY**

- **3) Individual development of organisms (clarification of the mechanisms of differentiation at all stages from protein synthesis to the appearance of specific cell properties, cell restructuring leading to the formation of organs; creation of a theory of ontogenesis).**

- **The life of every organism that develops sexually begins with a zygote - one fertilized cell (egg), as a result of repeated division of which many cells are formed, each of which contains a nucleus with a certain complete set of chromosomes (contains genes responsible for all the properties and characteristics of a particular organism. However, the development of each cell is different.**
- **Therefore, one of the main problems of developmental biology is the mechanism for turning on genes in the process cell differentiation.**

- **PROBLEMS OF MODERN BIOLOGY**



- **4) Rational organization of human life and development of the problem of life extension.**

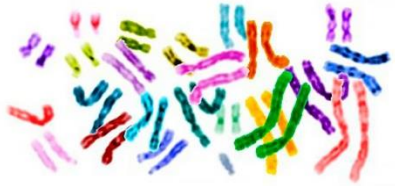
- **5) Biological aging (different theories of aging give different reasons why it occurs; the exact cause is not yet known, although there are genetic, mechanical and a number of other theories).**

- **6) The study of the mechanisms of brain activity in order to understand the patterns of thinking and memory processes.**

- **PROBLEMS OF MODERN BIOLOGY**

- **7) The development of organisms on the planet in the course of the history of its existence (disclosure of complex dependencies between adaptations of a fundamental nature acquired in the process of evolution or individual adaptations).**
- **A huge amount of facts confirmed the fundamental correctness of the evolutionary doctrine constructed by Charles Darwin. But still, many of its important provisions have not yet been developed.**

- **Therefore, an important task in the near future is to uncover complex dependencies between adaptations of a fundamental nature acquired in the process of evolution, or these are specific adaptations that lead to the development of a certain group (but i connection with the habitat).**

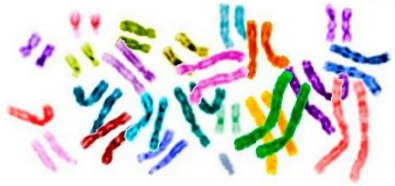


- **PROBLEMS OF MODERN BIOLOGY**

- **8) The origin of life (determining the causes and conditions for the origin of life on Earth, as well as modeling the processes that took place in this case, with the restoration of the successive stages of the arising of life on Earth by the method of experiment).**

- **9) The study of complex physiological and genetic functions of the body (for plants - the genetics of photosynthesis, nitrogen fixation, for animals - behavior, reactions to stress factors).**

- **10) Biosphere and humanity (the study of the biosphere as a dialectical unity of animate and inanimate nature, the most significant point for which is the circulation of matter and energy in nature; the study of the laws of the biosphere to characterize its state in a given period and predict the future of the planet and humanity**



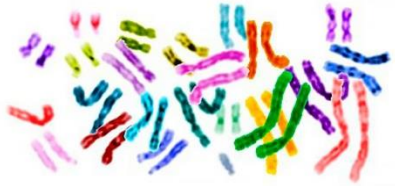
- **PROBLEMS OF MODERN BIOLOGY**

- **The study of the current state and development of promising areas in human economic activity on a planetary scale; a statement of the need to protect and increase wealth in order to maintain a balance in relations between nature and society.**

- **The rapid growth of the world's population raises the question of the limits of the biological productivity of the Earth's biosphere.**

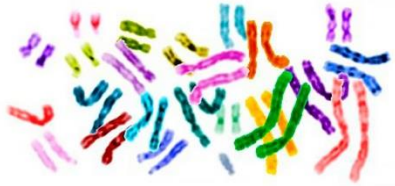
- **In 100-200 years, while maintaining modern methods of conducting the earth's economy and the same growth rate of the human population, almost half of the people would lack not only food and water, but also oxygen for breathing.**

- **PROBLEMS OF MODERN BIOLOGY**



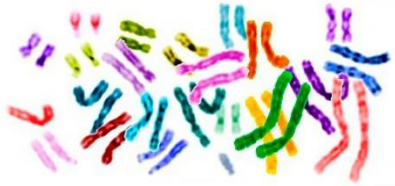
- **11) The problem of creating sufficient food potential for a growing human population (biotechnology, plant breeding - the creation of fundamentally new forms - more productive, high-quality and resistant to negative factors, with reconstructed genomes and more productive, the creation of transgenic plant species).**

- **PROBLEMS OF MODERN BIOLOGY**



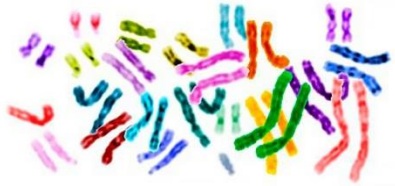
- **12) Biology and technology problems (the study of biological processes and the structure of living organisms in order to obtain new opportunities for solving scientific and technical problems (technical or industrial biochemistry, industrial microbiology); reproduction and modeling of biological processes and individual functions of organisms, as well as designing on basis of such prototypes of new technical systems and devices (problems of bionics).**

- **PROBLEMS OF MODERN BIOLOGY**



- **13) Biology and astronautics (study of the influence of outer space conditions on the body, possible consequences of the action of space factors, the mechanism of adaptation of organisms to the action of space conditions).**

- **PROBLEMS OF MODERN BIOLOGY**



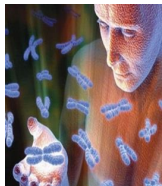
- **14) The development of genetic engineering (genetic reconstruction) (the most urgent task of the modern complex of natural sciences is to predict the long-term consequences of human intervention in natural processes).**
- **This task is being solved and will be solved on the basis of in-depth scientific research on the patterns of life phenomena.**
- **This is a new and important section of molecular biology, associated with the purposeful construction of new combinations of genes that do not yet exist in nature using genetic and biochemical methods, and one of the most important tasks is to predict the consequences of such construction in the future).**

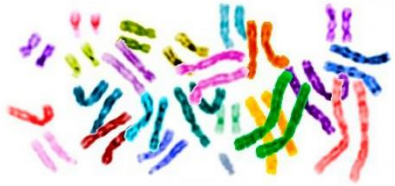
- **PROBLEMS OF MODERN BIOLOGY**

15) Deciphering the genomes of plants, animals and humans (the problem is to understand the processes of differentiation and development of gene sets, the creation of new artificial genomes, the replacement of defective sections of genomes, taking control of gene activity).

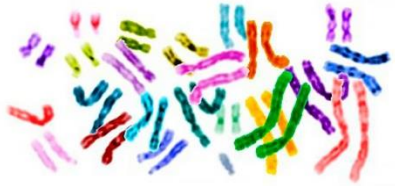
- **Biology can solve the problems facing it at the present stage only in close contact with other sciences: chemistry, physics, cybernetics, and other branches of science and technology.**

- **The solution of many issues of modern biology is still in the future.**





- **MODERN PROBLEMS OF PLANT GENETICS**



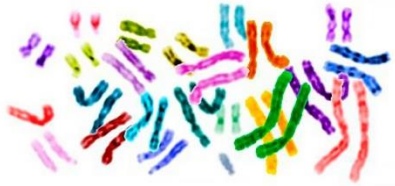
- **MODERN PROBLEMS OF PLANT GENETICS**

- **Obtaining high plant yield is not always achievable in agricultural activity as it is determined by various factors, including cultivar quality, nutrient and water supplies, degree of infection by pathogens, natural calamities and soil conditions, which affect plant growth and development.**

- **More noticeably, sustainable plant productivity to provide sufficient food for the increasing human population has become a thorny issue to scientists in the era of unpredictable global climatic changes, appearance of more tremendous or multiple stresses, and land restriction for cultivation.**

- **MODERN PROBLEMS OF PLANT GENETICS**

- **Well-established agricultural management by agrotechnological means has shown no longer to be effective enough to confront with this challenge.**
- **Instead, in order to maximize the production, it is advisable to implement such practices in combination with biological applications.**
- **Nowadays, high technologies are widely adopted into agricultural production, biological diversity conservation and crop improvement. the use of DNA-based technologies in this field would improve of plants.**



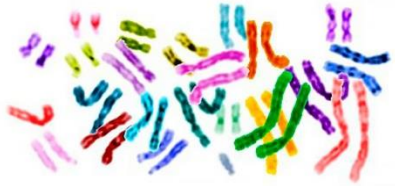
- **Agriculture and Plant Genomes**

- **Plant genome research is more than biology; it is also about producing food for our planet. Agriculture accounts for about 18% of U.S. jobs, 15% of the gross domestic product, and 31%of exports. Estimates are that agricultural research provides a**
- **35% return on the investment, and the value of agriculture is**
- **increasing rapidly as demand increases. The goals of agricultural plant science are to increase crop productivity, improve crop quality, and maintain the environment.**

- **Agriculture and Plant Genomes**

- **Traits of interest will include those related to crop protection to eliminate or reduce pesticides, prevent mycotoxin contamination, improve disease resistance to enable conservation tillage, improve herbicide resistance to allow use of safer, more effective, and cheaper herbicides;**

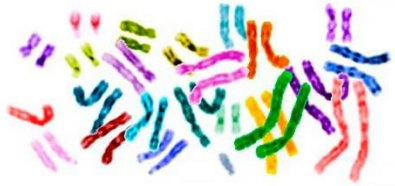
- **stress tolerance in regard to shading, cold, hypoxia, heat, water use efficiency, nutrient use efficiency, high-density planting tolerance; and improve grain quality, influencing quantity and quality of oil, protein, carbohydrates, nutrients, and novel substances.**



- **Agriculture and Plant Genomes**

- **We grow about 200 crops for food, feed, or fiber, and almost all were introduced to the U.S.; they were modified genetically to be adapted to climate and consumer desires.**
- **Clearly, genomics can help in issues related to food safety, food quality, and food diversity.**

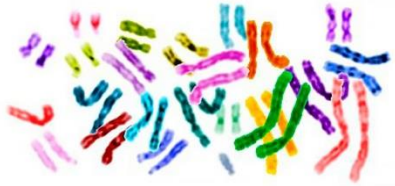
- **Genomics provides objectivity in breeding as never before possible; it allows hypothesis testing of quantitative genetics applications in plant improvement.**



- **MODERN PROBLEMS OF PLANT GENETICS**

- **Seminar 1**

- **High-throughput sequencing technology**



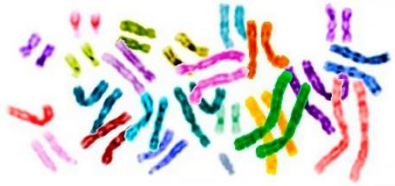
- **What is NGS?**

- **Next-generation sequencing (NGS) is a massively parallel sequencing technology that offers ultra-high throughput, scalability, and speed.**

- **The technology is used to determine the order of nucleotides in entire genomes or targeted regions of DNA or RNA. NGS has revolutionized the biological sciences, allowing labs to perform a wide variety of applications and study biological systems at a level never before possible.**

- **MODERN PROBLEMS OF PLANT GENETICS**

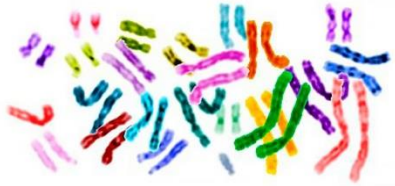
- **Among these are the applications of (i) DNA markers into cultivar identification, seed purity analysis, germplasm resource evaluation, heterosis prediction, genetic mapping, cloning and breeding; and (ii) gene expression data in supporting the description of crop phenology, the analytic comparison of crop growth under stress versus non-stress conditions, or the study of fertilizer effects. Besides, various purposes of using transgenic technologies in agriculture, such as generating cultivars with better product quality, better tolerance to biotic or abiotic stress.**



- **Seminar 1. High-throughput sequencing technology**
- **MODERN PROBLEMS OF PLANT GENETICS**

- **High-throughput sequencing technology, which is also known as next-generation sequencing (NGS). It is not so difficult to recognize that its application has allowed us to carry out biological studies at much deeper level and larger scale.**

- **The current global population is forecasted to cross ~9.8 billion in 2050 [1,2,3]. Several parts of the world are at risk of food insecurity [3]. After a consistent decline in crop production, the frequency of malnutrition in different world areas overturned the passage beginning in 2015 and has continued to climb.**



- **Today's complex genomics questions demand a dept information beyond the capacity of traditional DNA sequencing technologies. NGS has filled that gap and become an everyday tool to address these questions.**

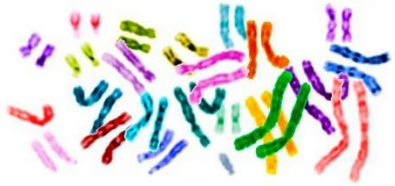
- **Applications of NGS**

- **Next-generation sequencing technology has fundamentally changed the kinds of questions scientists can ask and answer. Innovative sample preparation and data analysis options enable a broad range of applications.**

- **Applications of NGS**

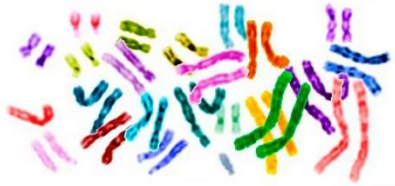
For example, NGS allows labs to:

- Rapidly sequence whole genomes
- Deeply sequence target regions
- Utilize RNA sequencing (RNA-Seq) to discover novel RNA variants and splice sites, or quantify mRNAs for gene expression analysis
- Analyze epigenetic factors such as genome-wide DNA methylation and DNA-protein interactions
- Sequence cancer samples to study rare somatic variants, tumor subclones, and more
- Study the human microbiome
- Identify novel pathogens



- **MODERN PROBLEMS OF PLANT GENETICS**

- **Malnutrition is predicted to increase up to 9.8% in 2030, presently soaring at ~9% worldwide, leading to a hunger crisis among ~850 million persons. Furthermore, agriculture production endures consuming a vast resource footmark, captivating ~38% of the surface area of the Earth and utilizing approximately 70% and 1.2% of fresh water and global energy resources, respectively, of the world [1,4].**
- **Besides agriculture consumption, other challenges include the degradation of agricultural land, urbanization, increasing water shortage, and dependence on carbon-economy-based synthetic inputs [1,5].**

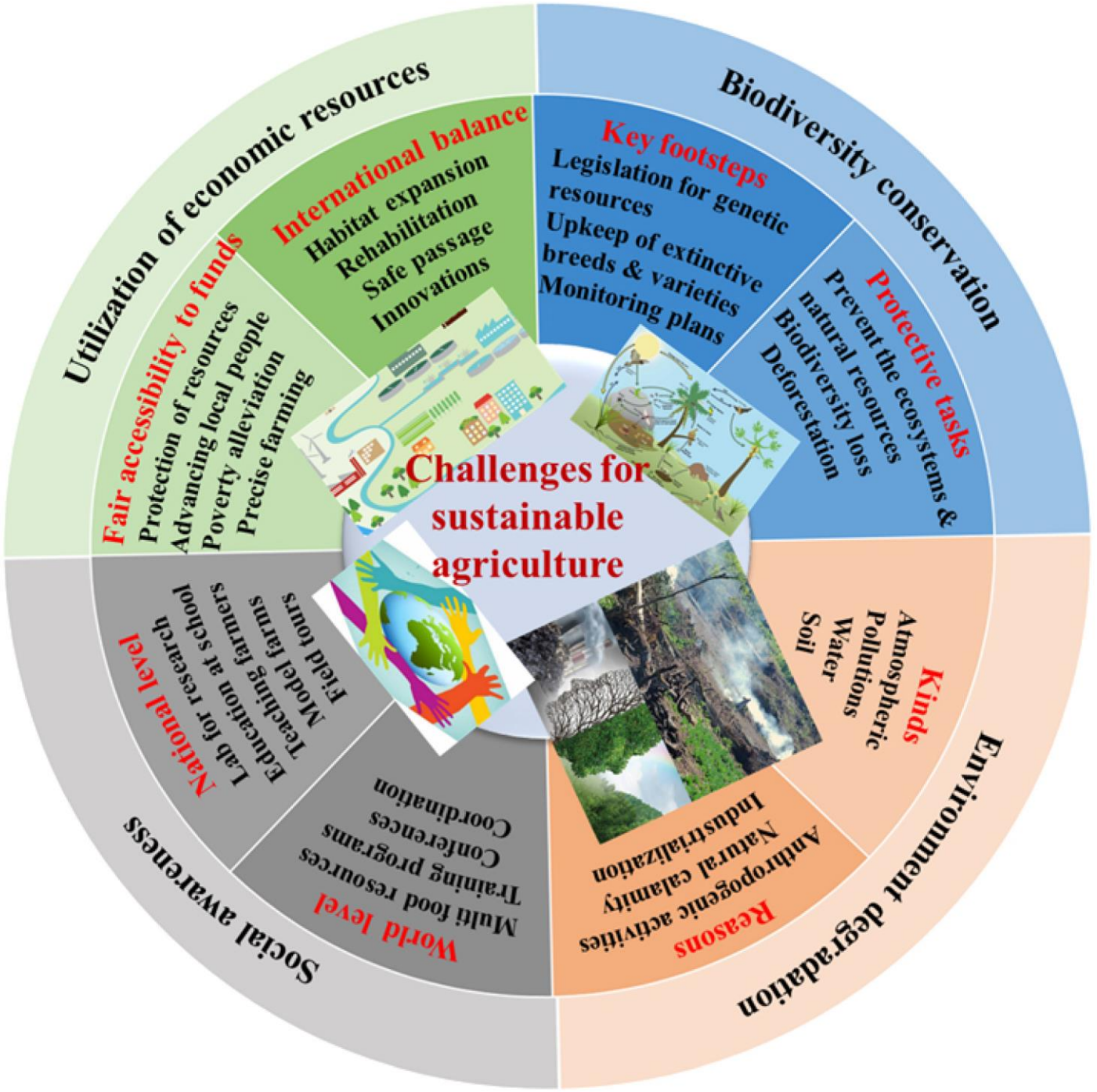


- **MODERN PROBLEMS OF PLANT GENETICS**

- **Agriculture production should be increased more as compared to the current progress in an ecofriendly, sustainable, and safe way [6,7]. After that, the food supply can be maintained to deliver enough food worldwide and avoid food insecurity events. Different types of plants have been domesticated to use as a food source and confront the huger events across the globe. Still, environmental alterations and biotic stresses have been the off-putting reason for reaching the targeted, sustainable crop yield. For example, biotic (pests, microbes, etc.) and abiotic (temperature variations, incidents of drought, salinity, etc.) stressors adversely affect agriculture production [4,8,9,10]**

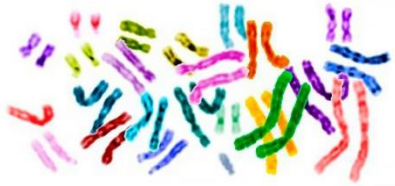
- **MODERN PROBLEMS OF PLANT GENETICS**

- **Therefore, feeding such a huge population will be a serious test along with creating livelihood opportunities, limited resources, and various global challenges as aforementioned to gain sustainable agriculture production (Figure 1).**



- **Figure 1. The key challenges for sustainable agriculture production. Four major challenges for agriculture and raising serious issues across the world.**

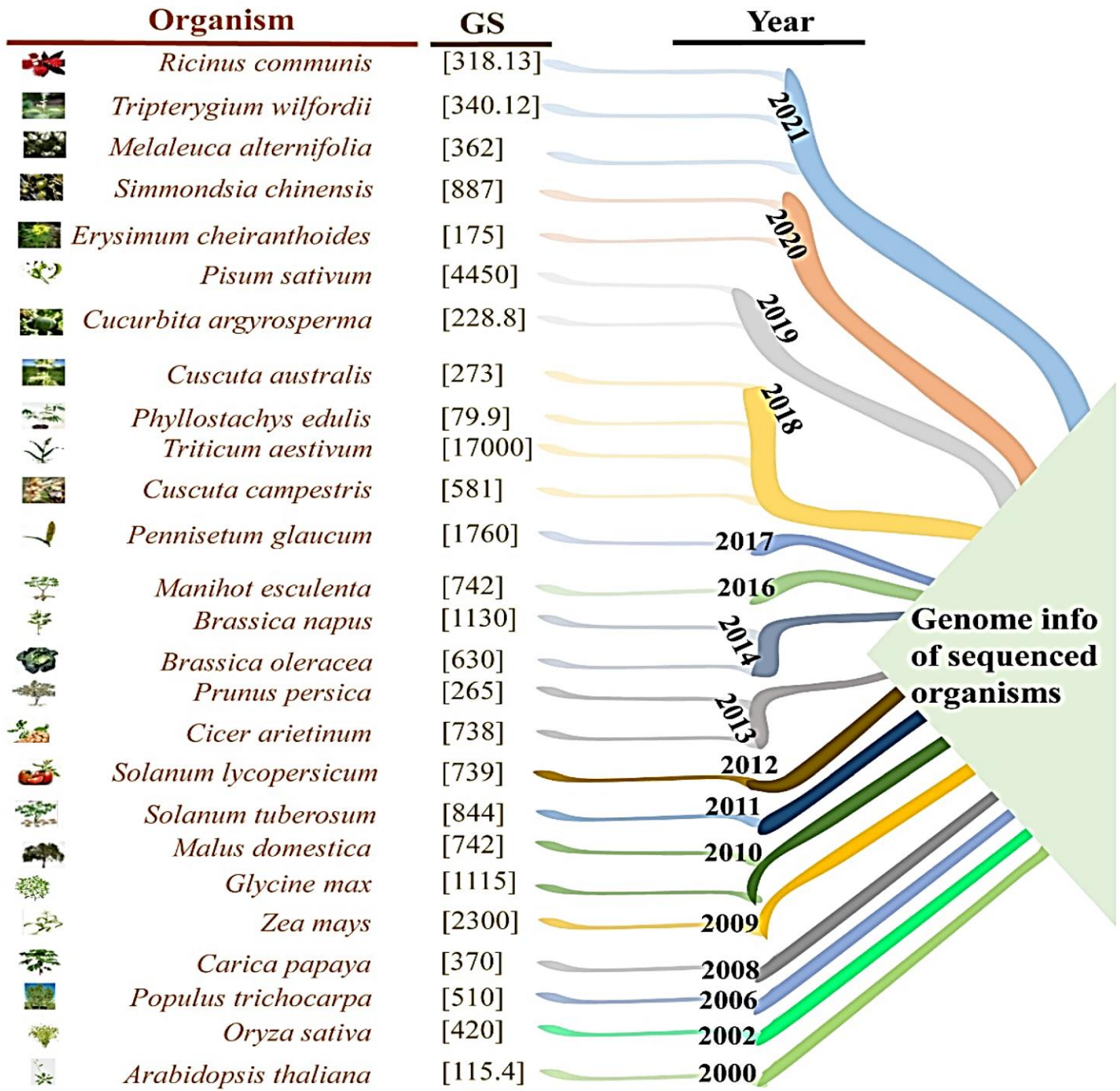
- **MODERN PROBLEMS OF PLANT GENETICS**



- **Therefore, humanity is under the threat of increasing world hunger, and the United Nations commission has set a goal, which is the Zero-Hunger Target by 2030. It is obligatory to achieve this goal by employing sustainable resources via safeguarding crop production in extreme environments while decreasing the resources indispensable to nourish a burgeoning global population. To entail a comprehensive system-centered technology that integrates innovative farming approaches, long-term sustainable agronomic practices, and value-added climate-resilient crops, genomic-based technologies offer, for this task, solid foundational tools and genetic tools insights for shaping the future agriculture [4].**

- **MODERN PROBLEMS OF PLANT GENETICS**

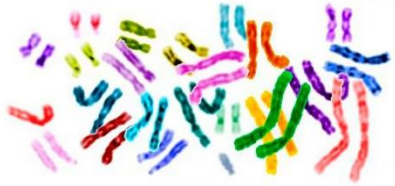
- **The whole-genome sequence (WGS) of Arabidopsis thaliana was developed 21 years ago, and later on, rice was the first crop in 2002 with available WGS and so on [11,12,13,14,15] (Figure 2).**



- **MODERN PROBLEMS OF PLANT GENETICS**

- **Access to the sequenced genome of various plants has exploited the potential genomic targets for improving the agronomic traits in crops. Genetic manipulations for desirable variations permit crop production, improving flexibility against harsh environments and pathogen stressors, and resulting in the generation of novel types of a plant [16,17,18]. Moreover, genomic is vital for advances in the crop sciences to fulfill the agriculture demands. Strategies related to genome sequencing have been improved to offer knowledge for crop enhancements during the last century [16]. Now, WGS data of the complex/polyploidy crops can be generated using NGS strategies such as long-read single-molecule sequencing strategy.**

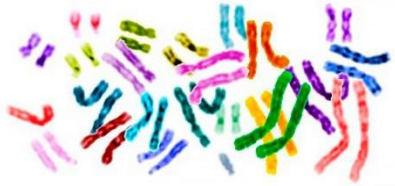
- **MODERN PROBLEMS OF PLANT GENETICS**



- **For example, the wheat genome (hexaploid) was generated through NGS [19,20,21,22].**

- **It is the fruit of the advancement in technologies, setting the stage to obtain elaborative information (info) by performing the genome-based interpretation of epigenomic data, consisting of the 3-D validation of the nucleus genome, the huge metabolome, transcriptome, and proteome [23,24,25].**

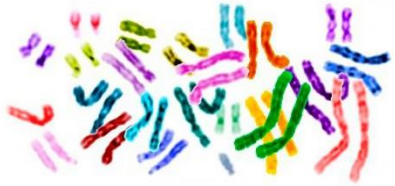
- **MODERN PROBLEMS OF PLANT GENETICS**



- **Robot-based technologies also help in gaining agriculture sustainability. For example, geosatellite imaging can forecast heatwave, drought, etc., events, and high-throughput phenology technologies and the involvement of drone technology have been used for planning a better strategy to improve crop production.**

- **Recent developments in the computational approaches to obtain detailed results about an individual or a big dataset by involving artificial intelligence are further strengthening our understanding of sustainable crop production [26,27,28].**

- **MODERN PROBLEMS OF PLANT GENETICS**



- **Robot-based technologies also help in gaining agriculture sustainability. For example, geosatellite imaging can forecast heatwave, drought, etc., events, and high-throughput phenology technologies and the involvement of drone technology have been used for planning a better strategy to improve crop production.**

- **Recent developments in the computational approaches to obtain detailed results about an individual or a big dataset by involving artificial intelligence are further strengthening our understanding of sustainable crop production [26,27,28].**

- **Control questions:**
- **What is the New Biology?**
- **Who is the new biologist?**
- **Problems of modern biology.**
- **Problems of modern plant genetics.**

- **Literature:**

- https://phdassistance.com/academy/subjects/research-methodology-in-biology-and-life-science/

- **bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_(Boundless)/01%3A_The_Study_of_Life/1.03%3A__The_Science_of_Biology_-_The_Scientific_Method-**
- https://www.khanacademy.org/science/high-school-biology/hs-biology-foundations/hs-biology-and-the-scientific-method/a/hs-biology-and-the-scientific-method-review


GOOD LUCK!