19. What is unique about adult stem cells?
(1) They can form any cell type (2) They are tissue-specific (3) They divide rapidly
(4) They can transform into embryonic cells (5) They are not specialized

20. Why is adult stem cell use limited?
(1) They divide too quickly (2) They are too few in number (3) They remain faithful to their origins
(4) They cannot be cultured (5) They cannot be transplanted

21. When were iPSCs first developed?
(1) Early 2005 (2) Mid 2006 (3) Late 2006 (4) Early 2007 (5) Late 2007

22. How many countries are mentioned as contributors to the Human Genome Project?
(1) Four (2) Five (3) Six (4) Seven (5) Eight

23. What was the duration of the Human Genome Project?
(1) 10 years (2) 11 years (3) 12 years (4) 13 years (5) 14 years

24. How many chemical base pairs make up human DNA?
(1) 2 billion (2) 2.5 billion (3) 3 billion (4) 3.5 billion (5) 4 billion

25. Which of these is NOT mentioned as an aim of the Human Genome Project?
(1) Store information in data bases (2) Identify protein coding genes (3) Develop new medical treatments
(4) Transfer technologies to private sector (5) Improve tools for data analysis

26. Which is NOT mentioned as a benefit of genome sequencing?
(1) Molecular medicine (2) Disease diagnosis (3) Agricultural development (4) Drug development
(5) Evolution studies

27. What was the project's accuracy goal?
(1) 98.99% (2) 99.00% (3) 99.50% (4) 99.90% (5) 99.99%

28. What property is associated with intergenic DNA?
(1) It has no known function (2) It always controls nearby genes (3) It has clear regulatory functions
(4) It contains protein-coding genes (5) It has well-understood roles

29. Which stem cells can proliferate indefinitely in culture?
(1) Adult stem cells (2) Neural stem cells (3) Hematopoietic stem cells (4) ES cells (5) Epidermal stem cells

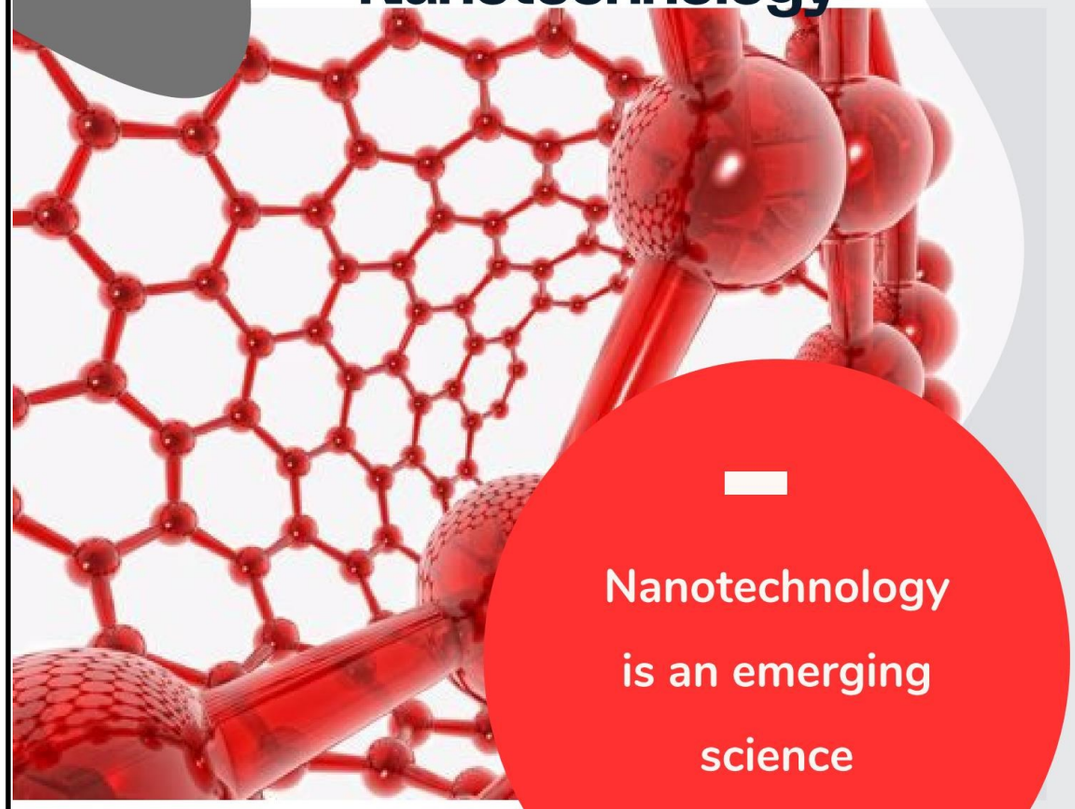
30. What makes iPSCs particularly valuable?
(1) They come from embryos (2) They are easily cultured (3) They can be patient-matched
(4) They divide rapidly (5) They are naturally occurring

AL 2025
REVISION

Unit 10

Applied Biology

Nanotechnology



Nanotechnology is an emerging science

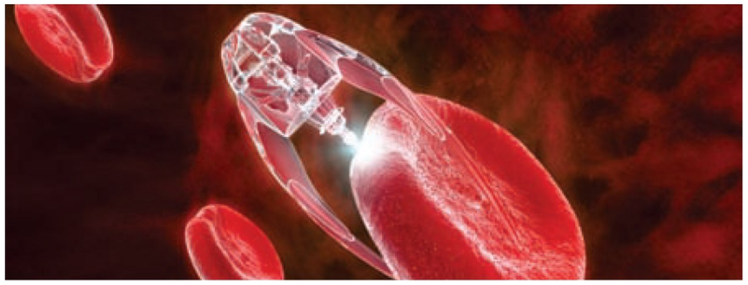
SAMPATH LANKADHEERA
B.Sc. (Hons), M.Sc.

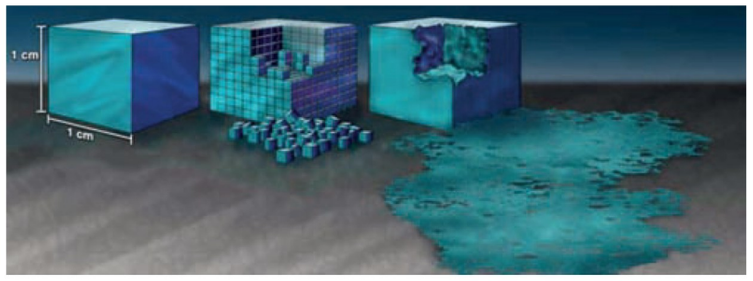
10.1.5 Gets updated in applications of emerging technologies related to biology

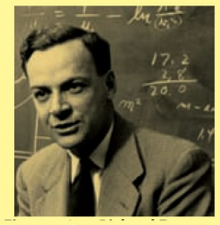
Number of Periods : 05

Nanotechnology

Nanotechnology is an emerging science involved in designing, building and manipulating minute structures at the nanometer level. A nanometer (nm) is one billionth of a meter (10^{-9} m). Nanotechnology is the creation and use of materials and devices on the same scale as molecules and intracellular structures, typically less than 100 nm in size. The physical and chemical properties of tiny molecules are significantly different than bigger particles as they have a very high surface area to volume ratio.







There's plenty of room at the bottom - Richard Feynman

American Physicist Richard Feynman in 1959 enlightened the world on nanotechnology. Living organisms are built of cells that are typically 10 µm across. However, the sub-cellular organelles are much smaller. Proteins are even smaller with a typical size of just 5 nm, which is comparable with the dimensions of smallest man made nanoparticles. This simple size comparison gives an idea of using nanoparticles as very small probes that would allow us to investigate the cellular machinery without introducing too much interference. Understanding of biological processes on the nanoscale level is a strong driving force behind development of nanotechnology. Nanotechnology has now become a big business with applications in material manufacturing, energy, electronics and engineering. But Applications of nanoparticles in biology and medicine are of particular interest. One of the most important applications of nanotechnology is in medicine. Applications of nanotechnology for improving human health are termed **Nanomedicine.** Nanotechnology can be applied for prevention, diagnosis and treatment of diseases.

7. Incorrect regarding ES cells.
(1) ES cells are so special because they can eventually differentiate to form all of the more than 200 cell types that make up the human body.
(2) ES cells are called totipotent because they have the potential to develop into a variety of different cell types.
(3) ES cells (hESCs) are unspecialized cells with two major properties.
(4) ES cells can self-renew indefinitely to produce more stem cells
(5) Under the proper growth conditions hESCs can differentiate into a variety of mature cells with specialized functions.

8. Correct statement regarding stem cells.
(A) When adult stem cells are removed from the body and maintained in culture or are transplanted from one site in the body to another, they generally remain faithful to their origins.
(B) If ES cells are put back into a blastocyst, they become incorporated into the embryo and can give rise to all the tissues and cell types in the body, including germ cells.
(C) There are ethical concerns of obtaining human embryonic stem cells. Therefore, research on eHSCs (embryonic human stem cells) is very controversial because of their source- an early embryo.
(1) A,B (2) A,C (3) B,C (4) All (5) None

9. Incorrect about human genome project.
(1) The genome projects will have additional benefits that at present can only be guessed at.
(2) It is evident that the human genome, contains extensive amounts of intergenic DNA.
(3) some intergenic DNA acts to control genes nearby.
(4) intergenic sequences are thought to have regulatory functions.
(5) role of all these intergenic sequences have identified.

10. Which of the following statements regarding genome projects are correct?
A - One of the aims of the human genome project is to determine the sequence of 20000 base pairs of human DNA.
B - Human genome project is yet to be completed.
C - Human Genome project has lead to the description of molecular activities of human cells.
D - Genome project of Escherichia coli is already completed.
(1) A and B only. (2) B and C only. (3) B and D only. (4) B, C and D only. (5) C and D only. 2023 Al/40

11. Stem cells
(A) can give rise to cells of the same type. (B) can divide without a limit. (C) are of three types.
(D) are undifferentiated cells. (E) divide rapidly. 2023/49

12. What is the size of a nanoshell compared to a polio virus?
(1) Much smaller (2) Slightly smaller (3) Equal (4) Slightly bigger (5) Much bigger

13. Which nanotechnology application is used for diabetes treatment?
(1) Nanoshells (2) Nano device for insulin release (3) Nanocomposites (4) Nano-formulated liposomes
(5) Nanocarrier systems

14. What are nanocomposites used for?
(1) Only broken bones (2) Only dental fillings (3) Both broken bones and dental fillings (4) Drug delivery
(5) Pain management

15. What is the approximate size of a blastocyst?
(1) One-third of a millimeter (2) One-fifth of a millimeter (3) One-seventh of a millimeter
(4) One-ninth of a millimeter (5) One-tenth of a millimeter

16. How many cells make up the entire blastocyst?
(1) About 30 cells (2) About 50 cells (3) About 75 cells (4) About 100 cells (5) About 150 cells

17. What can ES cells differentiate into?
(1) Only blood cells (2) Only nerve cells (3) About 100 cell types (4) More than 200 cell types
(5) Only specialized cells

18. Which statement about stem cells is correct?
(1) They divide rapidly (2) They cannot self-renew (3) They divide without limit in animals
(4) They always differentiate quickly (5) They only exist in embryos

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17. Write the benefits of sequencing of human genome.

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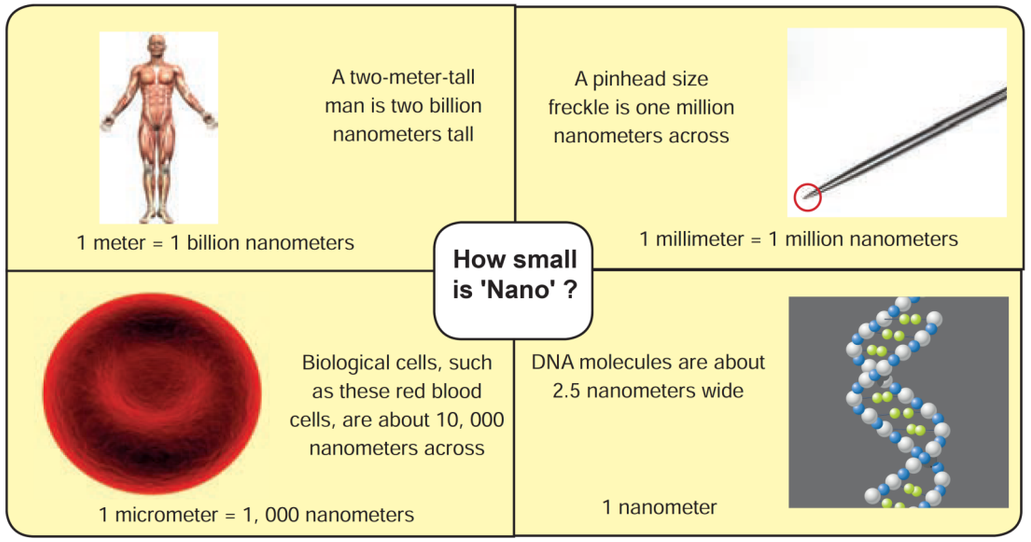
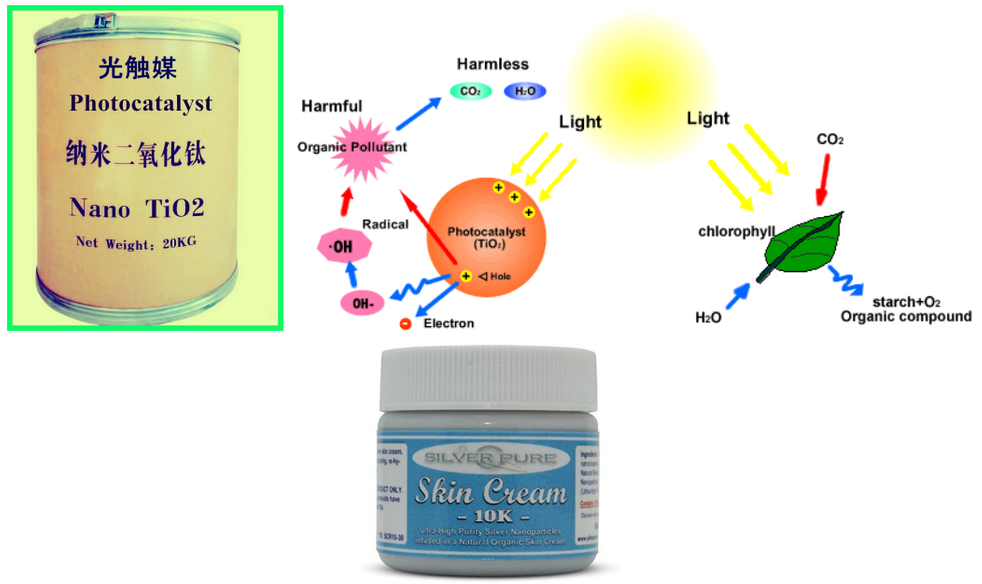
MCQ

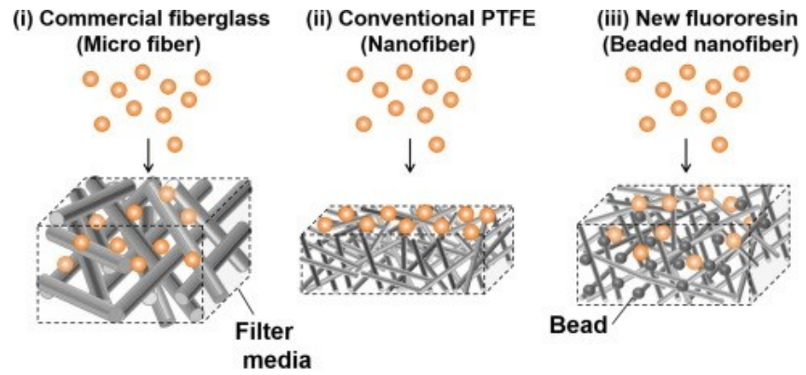
1. Incorrect about nanotechnology
   (1) Nanotechnology is an emerging science involved in designing, building and manipulating minute structures at the nanometer level.
   (2) A nanometer (nm) is one billionth of a milli meter (10^{-9} mm).
   (3) Nanotechnology is the creation and use of materials and devices on the same scale as molecules and intra-cellular structures, typically less than 100 nm in size.
   (4) The physical and chemical properties of tiny molecules are significantly different than bigger particles as they have a very high surface area to volume ratio.
   (5)American Physicist Richard Feynman in 1959 enlightened the world on nanotechnology.
2. Sect the incorrect statement about nanotechnology.
   (1) Proteins are even larger than with the dimensions of smallest manmade nanoparticles.
   (2) nanoparticles allow us to investigate the cellular machinery without introducing too much interference.
   (3) Understanding of biological processes on the nanoscale level is a strong driving force behind development of nanotechnology.
   (4) Nanotechnology has now become a big business.
   (5) It has applications in material manufacturing, energy, electronics and engineering.
3. Select wrong combination.
   (1) Titanium dioxide (TiO_2) and silver (Ag) nanoparticles - Sterilization of operation theatres.
   (2) TiO_2 and Silver - "smart drugs"
   (3) Nano device sensors - monitor blood pressure; blood oxygen levels and hormone concentrations.
   (4) Nano particles - unclog blocked arteries/detect and eliminate cancer cells.
   (5) gold particles - nano filters to examine SARS patients.
4. Find correct statements
   (A) Spherical nanoparticles consisting of a dielectric core called nanoshells
   (B) A nanoshell is similar to a polio virus.
   (C) Gold nano-shells are used as smart drugs and in bio imaging enhancements.
   (1) A (2) A,B (3) A,C (4) B,C (5) A,B,C
5. Select incorrect statement
   (1) In the treatment of diabetes a Nano device is attached to the body which can release the required dosage of insulin at required time intervals.
   (2) There has been successful application of nano-liposomes to deliver drugs for pain therapy
   (3) Since nano-carrier systems can be easily transferred to the airways, many respiratory diseases can be treated using nanotechnology.
   (4) Viva gel is a systemic microbicide in development for prevention of HIV and HSV (Herpes simplex virus) during sexual intercourse.
   (5) Nano-composites are used to replace broken bones and to fill teeth.
6. Incorrect regarding stem cells.
   (1) Stem cells are undifferentiated cells which can give rise to cells of the same type.
   (2) They can divide by mitosis without a limit.
   (3) They are capable of terminally differentiating into other cell types.
   (4) Stem cells are required wherever there is a need to replace differentiated cells that cannot themselves divide.
   (5) Stem cells usually divide at a relatively high rate.



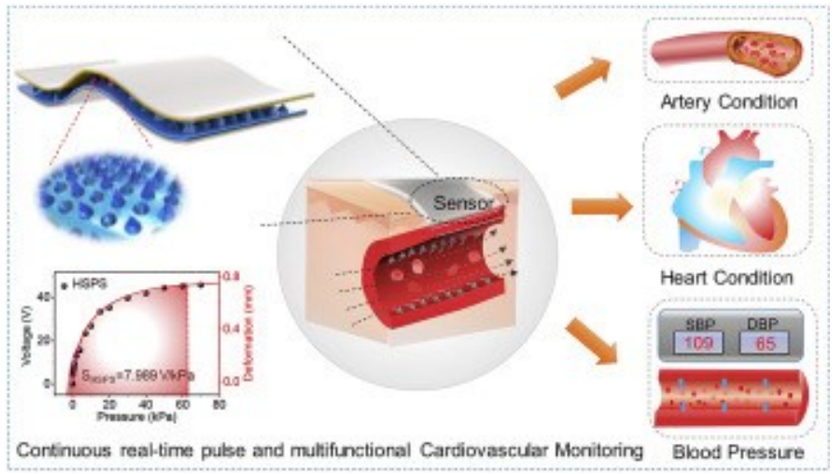
Titanium dioxide (TiO_2) and silver (Ag) nanoparticles are used for sterilization of operation theatres and surgical instruments in hospitals. These nanoparticles are able to destroy the microbes. Silver nano lotions are applied in theatres to prevent the entry of microbes.



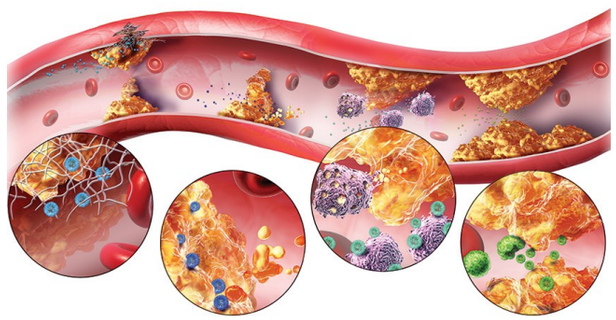
Nano particles are used in the production of antimicrobial coatings and nano - filters. TiO_2 and Silver nano filters prevent the entrance of tiny particles such as viruses. These nano filters are used to examine SARS patients.



Nano device sensors are used to monitor blood pressure; blood oxygen levels and hormone concentrations.



Nano particles can unclog blocked arteries and detect and eliminate cancer cells. Several nanotechnology enabled drugs are available in the market primarily in areas of cancer treatment.



Scientists have developed "smart drugs" using tiny nanoparticles such as gold particles that are introduced into the body to seek out and target special cells such as cancer cells to deliver a cargo that would destroy those that are damaged rapidly and effectively in a silent manner with very few side effects.

8. What are the two types of stem cells in humans?

   ……
   ……
   ……

9. What is the source of stem cells in the embryonic stage of humans?

   ……
   ……
   ……

10. Write the 2 major properties of the above mentioned cells.

    ……
    ……

11. What is the practical limitation of using adult stem cells for tissue regeneration?

    ……
    ……
    ……

12. What advantage is there in using embryonic stem cells?

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    ……
    ……
    ……

13. How is pluripotency induced in adult tissues?

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    ……

14. Write the advantages of using induced pluripotent stem cells ?

    ……
    ……

15. Write the applications of stem cells in various fields.

    ……
    ……
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16. Human genome project is a world wide effort to identify all the genes in every chromosome with several other goals. Indicate such goals of the human genome project.

    ……

5. Fill the following table

Type of nanoparticle	Applications in prevention/diagnosis/ treatment of diseases
Titanium dioxide and Ag nanoparticles	
Nano device sensors	
Smart drugs	
Nanoshells	
Nanodevices for treatments	
Nano-formulated liposomes	
Nanocarrier systems	
Vivagels	
Nanocomposites	

6. What are stem cells?

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7. What is the use of stem cells to the body?

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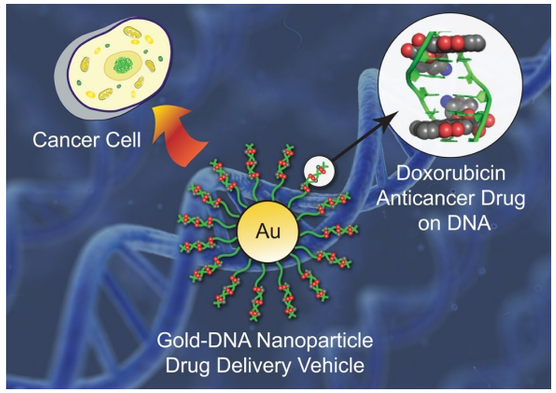


Spherical nanoparticles consisting of a dielectric core called nanoshells are used in the treatment of cancer. A nanoshell is slightly bigger than a polio virus. Gold nano-shells are used in bio imaging enhancements as well.

In the treatment of diabetes a Nano device is attached to the body which can release the required dosage of insulin at required time intervals.

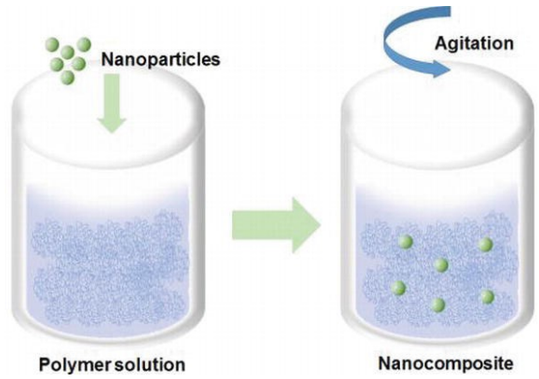
There has been successful application of nano-technology to the treatment and management of pain both in clinical and experimental studies like the fabrication of nano-formulated liposomes to deliver drugs for pain therapy.

Liposomes

Since nano-carrier systems can be easily transferred to the airways, many respiratory diseases can be treated using nanotechnology.

Viva gel is a vaginally applied microbicide in development for prevention of HIV and HSV (Herpes simplex virus). Viva gel is a product of nanotechnology which prevents the entry of HIV and HSV during sexual intercourse.

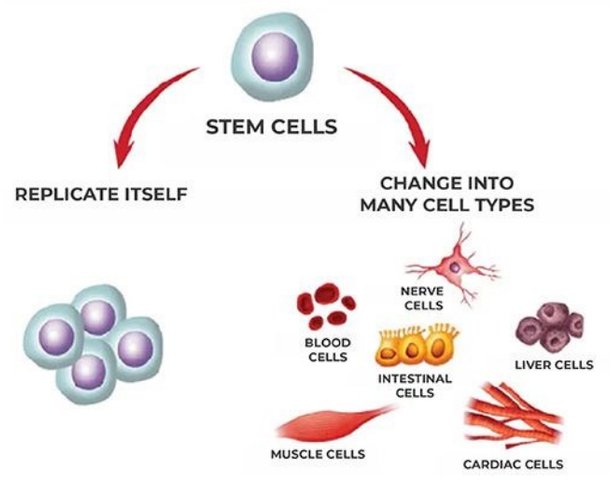
Nano-composites are used to replace broken bones and to fill teeth as well.



Stem Cell Therapy

Stem cells are undifferentiated cells which can give rise to cells of the same type. They can divide by mitosis without a limit (or at least for the lifetime of the animal). They are capable of terminally differentiating into other cell types.

Stem cells are required wherever there is a recurring need to replace differentiated cells that cannot themselves divide. The stem cell itself has to be able to divide but it doesn't necessarily have to divide rapidly. In fact, stem cells usually divide at a relatively slow rate.



- Stem cells are of two types.
  1. Embryonic stem cells
  2. Adult Stem cells

The Human Genome Project, and the other genome projects such as Escherichia coli, yeast, mouse, Arabidopsis thaliana, and rice have already been completed. This has therefore opened the way to a comprehensive description of the molecular activities of human cells and the ways in which these activities are controlled. This is central to the continued development, not only of molecular biology and genetics, but also of those areas of biochemistry, cell biology and physiology now described as the molecular life sciences.

The genome projects will have additional benefits that at present can only be guessed at. It is evident that the human genome, in common with the genomes of many other organisms, contains extensive amounts of intergenic DNA. It was thought that most of the intergenic DNA has no function except occasionally it is known that some intergenic DNA acts to control genes nearby. Could the intergenic DNA have a role, but one that at present is too subtle for us to grasp? Though little is known about them, they are thought to have regulatory functions. The first step in addressing this possibility is to obtain a complete description of the organization of the intergenic DNA in different genomes, so that common features, which might indicate a role for some or all of these sequences, can be identified.

Suggested Teaching Learning Process

Learning outcomes:

1. What is nanotechnology?

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2. What is the accepted scale the nanodevices should be of?

   ……

3. What is the main advantage when the particles are of nano size?

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4. What is understood by Nanomedicine?

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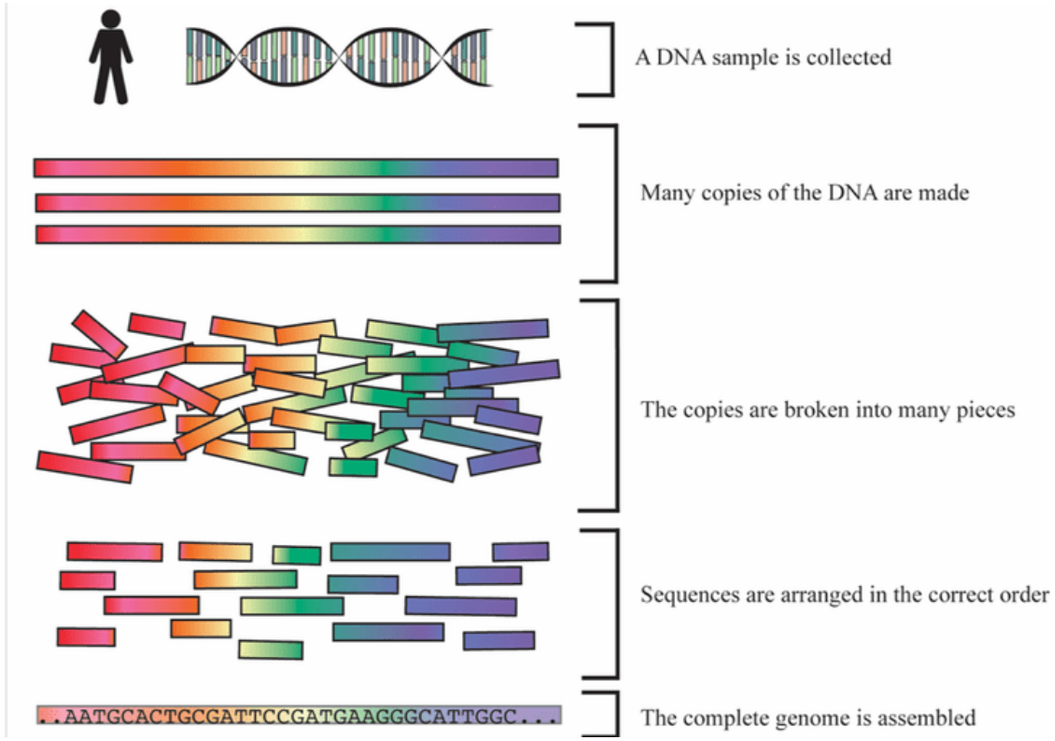


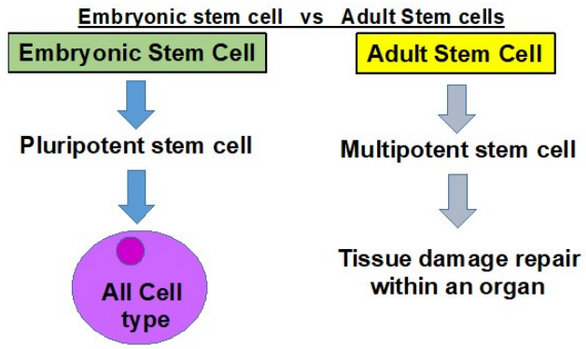
The aims of the project were to,

1. Identify all the genes (approximately 20,000 protein coding genes) in human genome
2. Determine the sequences of the 3 billion chemical base pairs that make up human DNA
3. Store information in data bases
4. Improve tools for data analysis
5. Transfer related technologies to private sector
6. Address, ethical, legal and social issues that may arise from the project.

A major quality assessment of the human genome sequence was published in 2004 indicating over 92% of sampling exceeded 99.99% accuracy which was within the intended goal. The Genome Reference Consortium (GRC) which is an international collective of academic and research institutes with expertise in genome mapping is still working on the analyses of the data obtained from the Human genome project.

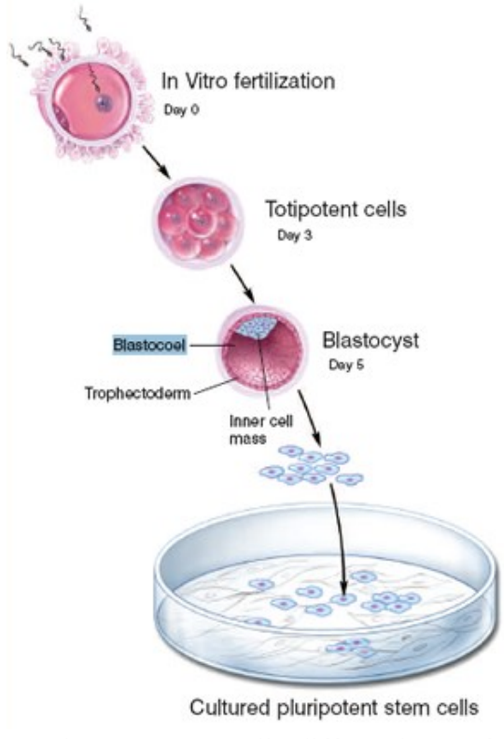
The sequencing of the human genome holds benefits for many fields, from molecular medicine to human evolution. Improved diagnosis of various diseases, identification of mutations linked to different forms of cancer, the design of medication and more accurate prediction of their effects, gene therapy and control systems for drugs, Study of human evolution and anthropology are some of them.

Another proposed benefit is the commercial development of genomics research related to DNA based products, a multibillion-dollar industry.



1. Embryonic stem cells

Following fertilization of a sperm and an egg cell, the fertilized egg is called a zygote. The zygote divides rapidly. In humans, in around five to seven days after fertilization, the dividing cells create an embryo consisting of a small hollow cluster of approximately 100 cells called a blastocyst. The blastocyst is approximately a seventh of a millimeter in diameter. There is a small cluster of around 30 cells tucked inside the blastocyst that form a structure known as the inner cell mass. These cells are the source of embryonic stem cells (ES cells).



ES cells are so special because they can eventually differentiate to form all of the more than 200 cell types that make up the human body. Therefore, ES cells are called pluripotent because they have the potential to develop into a variety of different cell types. Human ES cells (hESCs) are unspecialized cells with two major properties.

- ES cells can self-renew indefinitely to produce more stem cells
- Under the proper growth conditions hESCs can differentiate into a variety of mature cells with specialized functions.

2. Adult stem cells

Adult stem cells are found throughout the body after development. Adult stem cells are present In many tissues. There are many types of adult stem cells specialized for the genesis of different classes of terminally differentiated cells and hence each of stem cell serves for the renewal of one particular type of tissue.

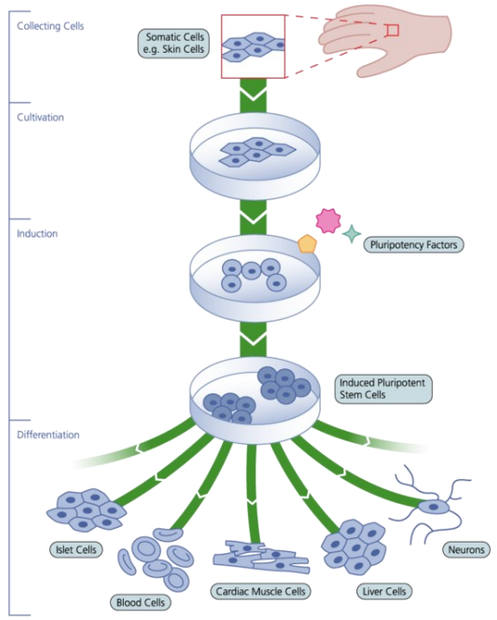
Eg. Epidermal stem cells for epidermis, Intestinal stem cells for intestinal epithelium, hemopoietic stem cells for blood, neural stem cells for central nervous system

Stem cells can be isolated and cultured in culture media in vitro. When adult stem cells are removed from the body and maintained in culture or are transplanted from one site in the body to another, they generally remain faithful to their origins. This creates practical limitation of using adult stem cells for tissue regeneration.

In contract, ES cells can be kept proliferating indefinitely in culture and yet retain unrestricted developmental potential. If ES cells are put back into a blastocyst, they become incorporated into the embryo and can give rise to all the tissues and cell types in the body, including germ cells. Under the proper growth conditions, human ES cells can differentiate into a variety of mature cells with specialized functions in vitro.

There are ethical concerns of obtaining human embryonic stem cells. Therefore, research on eHSCs (embryonic human stem cells) is very controversial because of their source- an early embryo.

In late 2006, Scientists demonstrated the successful derivation of pluripotent stem cells from adult tissues by reprogramming human cells taken directly from a volunteer. These are known as induced pluripotent stem cells (iPSCs). Pluripotent stem cells hold promise in the field of regenerative medicine because they can propagate indefinitely, as well as give rise to every other cell in the body (such as neurons, heart, pancreatic, and liver cells), they represent a single source of cells that could be used to replace those lost to damage or disease. Since iPSCs can be derived directly from adult tissues, they not only bypass the need for embryos, but can be made in a patient-matched manner, which means that each individual could have their own pluripotent stem cell line.



Applications of stem cells

There are many potential applications of stem cells from growing healthy tissues to studying them to understand and treat birth defects to genetic manipulation for delivering genes in gene therapy approaches. Creating whole tissues in the laboratory using tissue engineering is another potential application for repairing tissues such as damaged heart muscles and damaged spinal neurons. Blood stem cells (hemopoietic stem cells) taken from the bone marrow of a healthy immunologically compatible donor can be used to replenish bone marrow of patients with leukemia.

Scientists believe that stem cell technologies will play key roles in developing treatments for diseases such as stroke, heart disease, Parkinson disease, Alzheimer disease, diabetes and many more.

The Human Genome project

The human genome has been the focus of biological research for the last two decades and will continue to be the center of attention for many years to come. It is a worldwide effort to identify all human genes of each chromosome along with several other goals. The human genome project is an enormous undertaking in genomics that is providing scientists with exciting insight into human genes, their locations and functions. It was originally a 13 year project (1990-2003) coordinated by the US Department of Energy and the National Institutes of Health. Additional contributions came mainly from UK, Japan, France, Germany, Australia and China.