

The building blocks of life :

Chromosomes

Abstract:

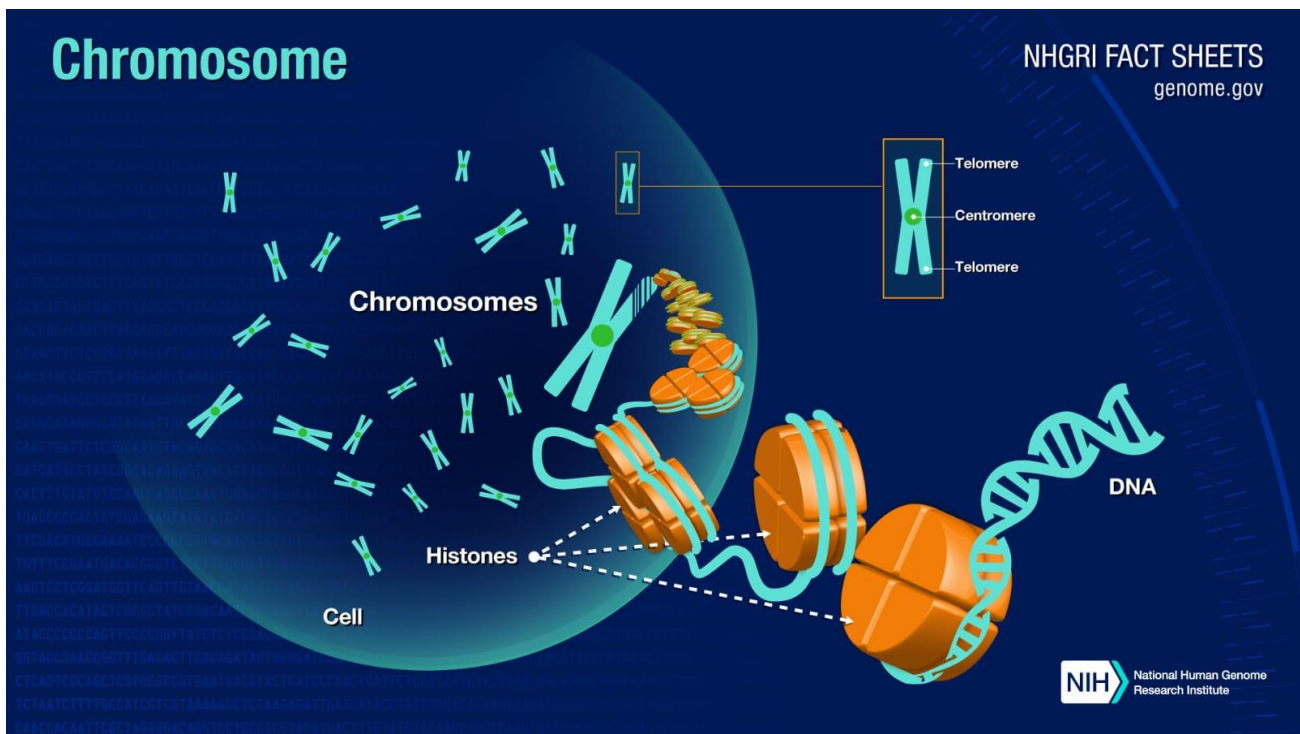
Chromosomes are thread like structures which is made up of DNA and proteins.

Chromosomes are crucial for the development, functioning and reproduction of living organisms. Chromosomes transport genetic information . Chromosomes are present in both prokaryotes and eukaryotes. In eukaryotes chromosomes are located in the nucleus whereas in prokaryotic chromosomes are located in the cytoplasm. In prokaryotes there is single chromosomes which is highly coiled DNA with distinct gene for proteins synthesis.

In eukaryotes cells chromosome are present in paired . It has one set from each parent . During cell division, chromosomes make sure that have accurate and equally distribution of genetic material. The study of chromosomes are important for understanding genetic disorders and inheritance with significant implications for medicine, biotechnology and evolutionary biology.

Chromosomes are a composition of DNA and wrapped with the histone protein, for forming chromatin and located within the cells of organisms.

Introduction



Chromosomes were first discovered by Walther Flemming in 1879. He was a German botanist who studied about the cell division in salamander embryos. He saw the structure of chromosomes. Chromosomes have a basic structure which transports genetic material in living cells.

Chromosomes are very important for inheritance, growth, and development and functioning of organisms. The composition of

DNA and histone proteins are made chromosomes. DNA is wrapped with histone proteins which formed a elaboration or complicated structure is called as chromatin. Chromosomes are present in both

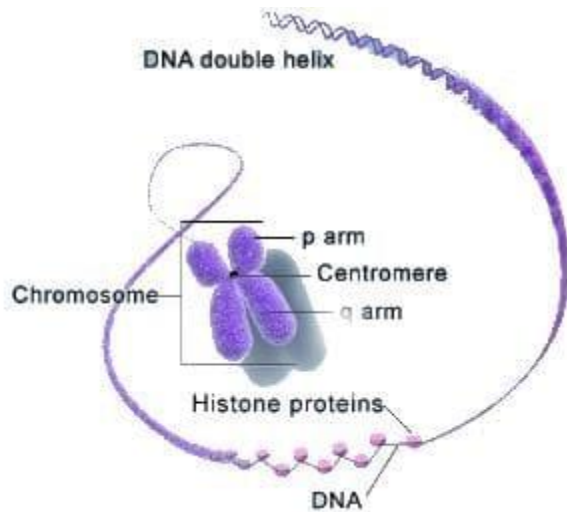
prokaryotic organisms and eukaryotic organisms .when we explore chromosomes in eukaryotic organisms it is found in the nucleus whereas if we explore chromosomes in prokaryotic it is found in cytoplasm . Each chromosomes contain a connected series of Gene's which give instruction for making proteins which derive traits and regulate the Cellular processes.

In human and most of the animal have pairs of chromosomes with one set inheritance from each Parent. In human beings total of chromosomes are 46 which is in 23 pairs.

During cell division, chromosomes are make sure that genetic materials are exact and correctly Copied and distributed to daughter cells. The study of chromosomes has often leading to substantial changes or long lasting

effects for genetic evolution and understanding of various Genetic diseases. In the help of reasearch in the chromosomes function structure can be better Understand that how genetic information is inherited and how it affect with health and diseases.

Chromosomes structure



The modification of DNA and chromatin

DNA (Deoxyribonucleic acid)

DNA can be defined as deoxyribonucleic

acid. DNA is a double helix structure which is made up of nucleotides which organised into

gene that is act as blue print for proteins synthesis.

In chromosomes 40 % of DNA present. DNA is a genetic material which is present all living Organisms . DNA carrying instruction for growth development and reproduction and cellular Functions. DNA has a negative charge due to phosphorus. DNA contains a sugar phosphate Group and nitrogenous base .

Chromatin

Chromatin is the complex structure of DNA and histone proteins which is found in nucleus of Eukaryotic cells . DNA griddle histone proteins to form nucleosome which is further fold and Coiled into higher order

structure which help DNA for packing and it regulates to transfer of Genetic information.

It's in relaxed state , it makes adequate chromatin transcription and DNA replication.

During cell Division chromatin contraction and it appears and change as chromosomes thereby ensuring Proper distribution of genetic material. Chromatin play a vital role in gene expression and Maintaining genomic integrity.

Chromosomes morphology

Chromosomes morphology defined as the physical form and the structure of chromosomes that transport genetic information and it highly organized. DNA stand , and it can be seen under the

microscope during cell division in mitosis or meiosis. The chromosomes are crucial for Understanding and essential for genetic inheritance and cellular function.

Chromosomes shape

METACENTRIC : The metacentric is area where two chromatids are constricted and joined Centromere. Centromere is located at the center and it equally divided two arm length . The Centromere is situated in the

center of chromosomes or medium in position. Two arms are equal in length and appear as V - shape.

SUB METACENTRIC : The centromere is metacentric sub median in position or placed near the midpoint. Arms are unequally in length, shows letter L in shape . The centromere is little bit different from center . It arm is longer than other arm.

TELOCENTRIC : The centromere is located at the end of the chromosomes. Telocentric is like rod shaped . It has only one arm .

ACROCENTRIC : It is near one end of the chromosomes centromere present. It is also rod shaped . It's one arm is short and one arm is long .

ARM LENGTH: Every chromosomes are divided into two sections or we can say that each chromosomes are divided into parts by constriction called centromere.

The two arm in which one is shorter which is generally symbolized with p arm and one is larger which is represented by q arm which is based on alphabetical order.

BANDING PATTERNS: Chromosomes are leave a coloured mark that is different to remove with exact to make something a different color e.g Giemsa stain .

The technique which is used to make chromosomes specific binding patterns which identified their structural abnormalities like deletion, duplication and translocation.

SIZE AND NUMBER: Chromosomes are present in all living organisms but it is different number of Chromosomes and different size of chromosomes. Example In human beings they are carrying 46 chromosomes that is arranged in 23 pairs that 22

Pairs of autosomes which have one pair of sex chromosomes (XX or XY) .

Chromosomes morphology is essential in genetics and cytogenetic which is for underlying the Genetic disorder or mutation.

Chromosomes function

Chromosomes play a important role in transfer of genetic material. In cell there is important structure which carry genetic material in the form of DNA . There functions are important for the right functioning of cell organisms development and inheritance.

THE STORAGE OF GENETIC INFORMATION

The genetic blueprint of an organism is stored by chromosomes. A DNA which is found in

chromosomes that contains Gene's which follow an order of number which is code for proteins and other molecules which control cellular functions and an inherited characteristic.

THE EXPERIENCE OF GENE

Chromosomes make easier to regulate the gene expression. The packing of DNA into chromosomes helps in controlling when and how genes are turn on and off which is important for cell differentiation and function.

CELL DIVISION

During mitosis and meiosis chromosomes are make sure that the accurate division and

distribution of genetic material between daughters cells. They make sure that genetic stability is extremely important for growth, development and reproduction.

INHERITANCE

Chromosomes carry genetic material that is passed from one generation to another generation. During reproduction, half of the chromosomes comes from each parent and make sure the transmission of genetic inherited characteristics.

DNA REPAIR AND STABILITY

Chromosomes play an important role in maintaining the honesty of DNA . DNA is involved in repairing process that fix

mutations damage maintain genomic stability and preventing disease Like cancer .

CHROMOSOMES NUMBER AND STRUCTURE INTERGITY

The number of chromosomes maintain the normal function of cell . If there is missing of chromosomes or more number of chromosomes must be caused genetic disorder such as down syndrome or Turner syndrome.

TELOMERE MAINTAINING

The protective cap of the chromosomes is telomere which is present at the end of the chromosomes. Chromosomes play an

important role in protecting chromosomes ends from cause the condition of something to become worse and make sure the stability of genetic information over time.

Protein synthesis help in carry or transfer of genetic information need for protein synthesis.

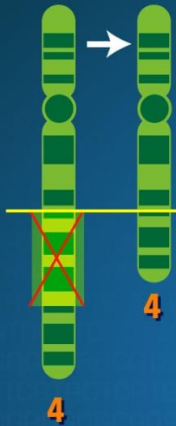
CHROMOSOMES ABNORMALITIES



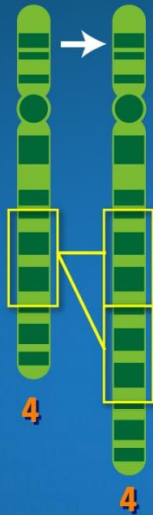
CHROMOSOME ABNORMALITIES

NHGRI FACT SHEETS
genome.gov

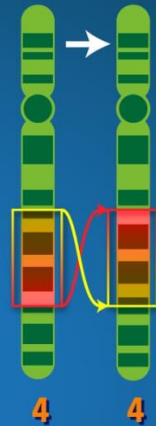
Deletion



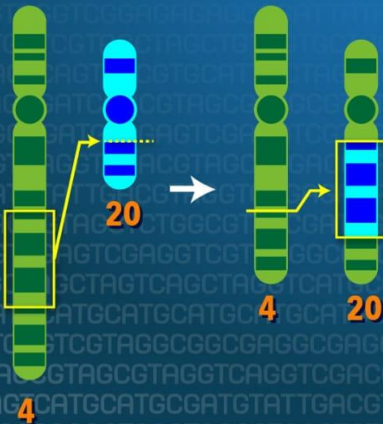
Duplication



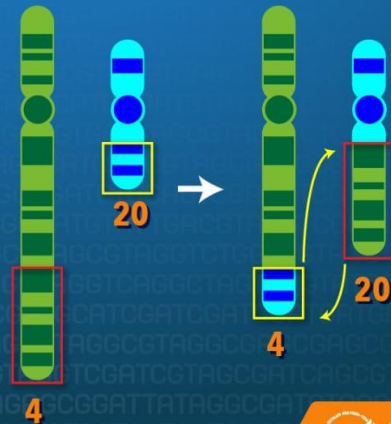
Inversion



Substitution



Translocation



NIH National Human Genome Research Institute

Chromosomes abnormalities refers to when there is a change in a number of chromosomes or structures of chromosomes. Chromosomes carry different genetic disorders and health conditions . These abnormalities can be classified into

numerical and structural changes each with

clearly different effect on an individual health and development.

NUMERICAL ABNORMALITIES

When there is a difference in the normal number of chromosomes the most common numerical abnormalities are aneuploidy which involves an extra or missing chromosome. If there is an extra chromosome it occurs Trisomy (it refers to the presence of extra chromosomes in some or all of the body cells) such as Down syndrome (Trisomy 21), which leads to intellectual disability. Its characteristics are facial features and heart defects. Other trisomies include Patau syndrome (Trisomy 13) and Edward syndrome (Trisomy 18).

both of these are associated with serious Development and physical challenges.

Monosomy is refers to the loss of the chromosomes it is seen in Turner syndrome, where a female has only one X chromosomes causing to infertility and different physical abnormalities.

STRUCTURAL ABNORMALITIES

It is defined as the change in the structure of the chromosomes is known as structural abnormalities such as duplication, deletion, inversion, and translocation. A deletion occurs when a portion of chromosomes is missing that cause Cri-du-chat syndrome

which causes delay development and it easy to recognize because it is different from other things and cry - Like - cat . The repetition of chromosomes segment is known as duplication. It causes Charcot marie tooth disease. When a segment of chromosomes is break off and rotate in 180 degree and re attach is called as inversion. It sometimes causing problems during cell division. When a chromosomes segment is moved to a different chromosome will be happened in translocation which deal with the genetic disorder like Chronic myelogenous Leukemia (CML) caused by a Philadelphia chromosomes translocation. It is a form of cancer . It is early act of saying exactly the what is the illness of a person has or What the causes of a problem through genetic test

, like Karyotyping and FISH is a very important for managing these diseases and improve patient care.

IMPLICATIONS AND DIAGNOSIS

Chromosomal abnormalities are found in living organisms . The rate of chromosomes abnormalities increased day by day . Its make much risk of cancer . Chromosomal abnormalities have that feel very strongly and the effect that something will have or something else in the future , to continue with great force from development disorders to increased cancer risk. There is many modern techniques by which the orders will be identifying a disease or sign and symptoms are tested by such as karyotyping

,FISH and a CGH are essential in to discover something that is difficult to see and feel and understand these something that is not normal in a person's body or unusual part or features of it that may be worrying or dangerous to help somebody in early what the cause of a problem is give you information about how genetic conditions might affect you or your family or it can be say that genetic counseling, a plan of creates clarity for treatment understanding about the chromosomal abnormalities is important for advancing medical care and genetic research.

CHROMOSOMES AND HUMAN DISEASES

Chromosomes abnormalities are defined as the change in the number of chromosomes and structures of chromosomes that are causes different or various human diseases.

Numerical abnormalities caused Down syndrome , it trisomy 21 is a genetic condition which is caused by the chromosomes . In the normal babies there is 23 number of chromosomes in pair from each parent it total number of chromosomes

is 46. But a child with Down syndrome are end there three chromosomes at the position 21 without pair , it characterized by a person ability to think in a logical way and to understand disability and physical features like a flat face and Turner syndrome have 45,X number of chromosomes a condition affecting female with short height and infertility.

Klinefelter syndrome its chromosomes number is 47,XXY . This is mainly caused in man caused infertility and development challenges. Structural abnormalities are effect with the structure of chromosomes its cause by cri-du-chat syndrome , which caused by deletion of chromosomes which carry intellectual disability and clearly seen in facial features. Fragile X syndrome caused

by the change in the basic structure of living organisms or development things in the chromosomes X, its results in late development and difficult in social. When the number of chromosomes is break off in pieces of 9 and 22 trade place which made an abnormalities refers to Philadelphia chromosomes . It caused the cancer its name is CML Chronic myelogenous leukemia. It is a type of cancer which treat or diagnosis through genetic testing like karyotyping and FISH it is an important for managing these diseases and improving patient care.

CANCER AND CHROMOSOMAL INSTABILITY CIN

Cancer and chromosomal instability is defined as the rate of chromosomes is increased and chromosomal are changes which involve the abnormal number of chromosomes and structural rearrangement or sequenced like translocation and deletion and fault during cell division in chromosomes discontinuity or chromosomal separation. These abnormalities conducted or managed to the loss or gain of the chromosomes or chromosomes section, which break the

normal genetic balance and increase cancer causing chance .

CIN cancer and chromosomal instability are difficult to connected with CIN being a helper or assistant to cancer development and progression. In cancer cells, an abnormal number of chromosomes is result in the over expression of causing development of tumour or the loss of tumors suppressors Gene's the growth of the cell is uncontrolled to contribute. Chromosomal translocation like an abnormal chromosome the Philadelphia chromosomes in chronic

Myelogenous Leukemia CML creates a hybrid gene which is form by join parts of two or more original genes that increase the abnormal cell progress . Furthermore, mitosis mistake such as reject the spindle

apparatus which manage to the unequal distribution of the chromosomes, further it fueling tumors heterogeneity and progression.

CIN accelerates cancer by allowing to the store of a change in genetic structure of living being or developing thing that help to stop something happening or to fight back among therapy avoid immune deletion and meat sizes.

As a result CIN is in many cases connected to more aggressive to fight with cancer and poor Prognosis. CIN planned a pathway is used to treat with the cancer such as spindle inhibition or DNA repair agent which block a cellular receptor are reasearch for limit growth of tumour and improve treatment which come in cancer patients. methods that have to usually improve the ability to entire map and the complete set of

Gene's in a cell with outstanding the quality. The progress in chromosomes reasearch is to use force to move some body the boundaries of genomic providing new treatments tools , treatments option and enhanced understanding of biology.

CONCLUSION

Chromosomes are important structures in the cell which carry genetic information to another generation. Chromosomes are made up of DNA and proteins and are responsible for making sure the genetic material is correctly replicated and distributed during cell division. In human there is 46 chromosomes are present and it is arranged in pairs which is 23 pairs where one set is inherited from each parent chromosomes play an extremely important role in expression of gene , inheritance, and the functioning of living organisms. In the field of genetic , medicine and evolution of biology

chromosomes play a vital role we can define chromosomes is a thread like structure which is made up of DNA and histone proteins that is found in the nucleus of the eukaryotic cells. They carry genetic information which is extremely important for development of growth and reproduction. In human there are a 23 pair of chromosomes which one set inherited from each parent every chromosomes have a thousand number of genes which encode the instructions for producing proteins that is performed essential for cellular functions.

During cell chromosomes make sure that the transfer of genetic material should be correct and accurate particularly in the processes like mitosis and meiosis which is important for the both sexual and sexual reproduction. Change in the number of chromosomes or in the structure of chromosomes can guidance to genetic disorders. Such as Down syndrome or Turner syndrome.

The study of the chromosomes or cytogenetic has provide a important way to understand the life of biological processes and their importance heredity, genetic diseases and evolutionary Biology.

REFERENCES

1. Zacharias, Helmut. "Key word: chromosome." Chromosome Research G (2001): 345-355.
2. Lewis, Jenny, and Colin Wood-Robinson. "Genes, chromosomes, cell division and Inheritance-do students see any relationship?." International journal of science education 22.2(2000): 177-195.
3. Spector, David L. "The dynamics of chromosome organization and gene regulation." Annual Review of biochemistry 72.1 (2003): 573-608.
4. Sumner, Adrian T. Chromosomes: organization and function. John Wiley C Sons, 200.
5. Mirsky, A. E., and Hans Ris. "The composition and structure of isolated

chromosomes.” The Journal of general physiology 34.5 (1951): 475

6. Alberts, Bruce, et al. “Chromosomal DNA and its packaging in the chromatin fiber.” Molecular Biology of the Cell. 4th edition. Garland science, 2002.

7. Bendich, Arnold J., and Karl Drlica. “Prokaryotic and eukaryotic chromosomes: what’s the Difference?.” Bioessays 22.5 (2000): 481-486.

8. Cavalier-Smith, Thomas. “Origin of the cell nucleus, mitosis and sex: roles of intracellular Coevolution.” Biology direct 5 (2010): 1-78.

9. Britten, Roy J., and Eric H. Davidson. “Gene Regulation for Higher Cells: A Theory: New Facts regarding the organization of the genome provide clues to the nature of gene Regulation.” Science 165.3891 (1969): 349-357.

10. Sutton, Walter S. "The chromosomes in heredity." *The Biological Bulletin* 4.5 (1903): 231-250.

11. Dunham, I., Hunt, A.R., Collins, J.E., Bruskiewich, R., Beare, D.M., Clamp, M., Smink, L.J., Ainscough, R., Almeida, J.P., Babbage, A. and Bagguley, C., 1999. The DNA sequence of human Chromosome 22. *Nature*, 402(6761), pp.489-495.

12. Lewis, Jenny, and Colin Wood-Robinson. "Genes, chromosomes, cell division and Inheritance-do students see any relationship?." *International journal of science education* 22.2 (2000): 177-195.

13. Kaessmann, Henrik. "Origins, evolution, and phenotypic impact of new genes." *Genome Research* 20.10 (2010): 1313-1326.

14. Lupski, James R. "Genomic disorders: structural features of the genome can lead to

DNA Rearrangements and human disease traits.” Trends in genetics 14.10 (1998): 417-422.

15. James, Havey M. “Overview of deoxyribonucleic acid (dna).” INOSR Scientific Research 2 (2016): 1-6.

16. Shakoori, Abdul Rauf. “Organization of Genetic Material into Chromosomes.” Chromosome Structure and Aberrations (2017): 41-73.

17. Kornberg, Arthur, and Tania A. Baker. DNA replication. University Science Books, 2005.

18. Sundaralingam, M. “Stereochemistry of nucleic acids and their constituents. IV. Allowed and Preferred conformations of nucleosides, nucleoside mono-, di-, tri-, tetraphosphates, nucleic Acids and polynucleotides.” Biopolymers: Original Research on Biomolecules 7.6 (1969): 821-860.

19. Simpson, Robert T. "Structure and function of chromatin." *Adv Enzymol Relat Areas Mol Biol* 38 (1973): 41-108.
20. Jha, Rajiv Kumar, David Levens, and Fedor Kouzine. "Mechanical determinants of chromatin topology and gene expression." *Nucleus* 13.1 (2022): 95-116.
21. Ehrenhofer-Murray, Ann E. "Chromatin dynamics at DNA replication, transcription and Repair." *European Journal of Biochemistry* 271.12 (2004): 2335-2349.
22. Kloc, Malgorzata, and Jarek Wosik. "Mechanical Forces, Nucleus, Chromosomes, and Chromatin." *Biomolecules* 15.3 (2025): 354.
23. Sumner, Adrian T. *Chromosomes: organization and function*. John Wiley C Sons, 2008.
24. Murray, Andrew W., and Jack W. Szostak. "Chromosome segregation in mitosis and

Meiosis.” Annual review of cell biology 1.1 (1985): 289-315.

25. Sumner, Adrian T. Chromosomes: organization and function. John Wiley C Sons, 2008.

26. Rhoades, M. M. “Studies of a telocentric chromosome in maize with reference to the stability Of its centromere.” Genetics 25.5 (1940): 483.

27. Madian, Nirmala, et al. “Identifying centromere position of human chromosome images using Contour and shape based analysis.” Measurement 144 (2019): 243-259.

28. Vajpayee, Manisha. “Chromosome Nomenclature and Cell Division.” Manual of Cytogenetics in Reproductive Biology (2014): 10.

29. Rhoades, M. M. “Studies of a telocentric chromosome in maize with reference to the

stability Of its centromere.” Genetics 25.5 (1940): 483.

30. McStay, Brian. “The p-arms of human acrocentric chromosomes play by a different set of rules.” Annual review of genomics and human genetics 24.1 (2023): 63-83.

31. Vershinin, Alexander Vasilievich. “The chromosome centromeres are separated. Centromeres.” Drugs (2020).

32. Saridis, George N., and Harry E. Stephanou. “A hierarchical approach to the control of a Prosthetic arm.” IEEE Transactions on Systems, Man, and Cybernetics 7.6 (1977): 407-420.

33. Shankland, Nikki Everts. “An examination of the chromosomes of several plant species using Giemsa-banding techniques.” (1975).

34. Montazerinezhad, Somayeh, Abbasali Emamjomeh, and Behzad Hajieghrari. “Chromosomal Abnormality, laboratory

techniques, tools and databases in molecular cytogenetics.” *Molecular Biology Reports* 47.11 (2020): 9055-9073.

35. Sumner, Adrian T. *Chromosomes: organization and function*. John Wiley & Sons, 2008.

36. Ohno, Susumu. *Sex chromosomes and sex-linked genes*. Vol. 1. Springer Science & Business Media, 2013.

37. Gardner, R J M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. *Chromosome abnormalities and Genetic counseling*. No. 61. OUP USA, 2012

38. Aguilar, Logan. *Genes, genomes, genetics and chromosomes*. Scientific e-Resources, 2019.

39. Aguilar, Logan. *Genes, genomes, genetics and chromosomes*. Scientific e-Resources, 2019.

40. Sumner, Adrian T. Chromosomes: organization and function. John Wiley C Sons, 2008.
41. Murray, Andrew W., and Jack W. Szostak. "Chromosome segregation in mitosis and Meiosis." Annual review of cell biology 1.1 (1985): 289-315.
42. Reik, Wolf. "Stability and flexibility of epigenetic gene regulation in mammalian Development." Nature 447.7143 (2007): 425-432.
43. Morgan, Thomas Hunt. "Chromosomes and heredity." The American Naturalist 44.524 (1910):449-496.
44. Alhmoud, Jehad F., et al. "DNA damage/repair management in cancers." Advances in Medical Biochemistry, Genomics, Physiology, and Pathology (2021): 309-339.

45. Zinn, Andrew R., David C. Page, and Elizabeth MC Fisher. "Turner syndrome: the case of the Missing sex chromosome." Trends in Genetics 9.3 (1993): 90-93.

46. Rodier, Francis, et al. "Cancer and aging: the importance of telomeres in genome Maintenance." The international journal of biochemistry C cell biology 37.5 (2005): 977-990.

47. Crick, Francis H. "On protein synthesis." Symp Soc Exp Biol. Vol. 12. No. 138-63. 1958.

48. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. Chromosome abnormalities and Genetic counseling. No. 61. OUP USA, 2012.

49. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. Chromosome abnormalities and Genetic counseling. No. 61. OUP USA, 2012.

50. Doebling, Scott W., et al. "Damage identification and health monitoring of structural and Mechanical systems from changes in their vibration characteristics: a literature review." (1996).

51. Patient, A. C. "abnormalities of chromosome number (aneuploidy)." Basic Science

In Obstetrics and Gynaecology E-Book: Basic Science in Obstetrics and Gynaecology E-Book (2014): 13.

52. Patwardhan, Dhruti, S. A. Varshini, and Latha Galoth. "Study of Chromosome." Genetics Fundamentals Notes. Singapore: Springer Nature Singapore, 2022. 239-298.

53. Pandey, Priyanka, and Rakesh Kumar Verma. "A Brief Overview on Autosomal Trisomies."

54. Bondy, Carolyn A., and Clara Cheng. "Monosomy for the X chromosome." *Chromosome Research* 17 (2009): 649-658.
55. Theisen, Aaron, and Lisa G. Shaffer. "Disorders caused by chromosome abnormalities." *The Application of clinical genetics* (2010): 159-174.
56. Campbell, Dennis J. Early development of individuals with Cri-du-chat syndrome.
57. Lupski, James R., et al. "DNA duplication associated with Charcot-Marie-Tooth disease type1A." *Cell* 66.2 (1991): 219-232.
58. Shakoori, Abdul Rauf, Saira Aftab, and Khalid Al-Ghanim. "Structural changes in Chromosomes." *Chromosome Structure and Aberrations* (2017): 245-274.
59. Lalwani, Kiran, and Shivani Sheth. Study of The Mechanism of Translocation in Chromosomes. Diss. Institute of Science, 2017.

60. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. Chromosome abnormalities and Genetic counseling. No. 61. OUP USA, 2012.
61. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. Chromosome abnormalities and Genetic counseling. No. 61. OUP USA, 2012.
62. Jain, S. Lochlann. Malignant: How cancer becomes us. Univ of California Press, 2013.
63. Silva, Joana Soraia Martinheira da. Internship in Laboratorial Clinical Genetics. MS thesis. 2022.
64. Hoedemaekers, Rogeer, and Henk Ten Have. "The concept of abnormality in medical Genetics." Theoretical Medicine and Bioethics 20 (1999): 537-561.
65. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. Chromosome

abnormalities And genetic counseling. No. 61. OUP USA, 2012.

66. Eggermann, Thomas, and Gesa Schwanitz. “Genetics of Down syndrome.” Genetics and Etiology of Down Syndrome, Part 1 (2011): 5-22.

67. Simpson, Kara L. “Syndromes and inborn errors of metabolism.” Children with Disabilities (2013): 757-801.

68. Bhoumik, Sukanya, and Syed Ibrahim Rizvi. “Genes in Genetic Disease.” Biotechnology in the Modern Medicinal System. Apple Academic Press, 2021. 121-136.

69. Patwardhan, Dhruti, S. A. Varshini, and Latha Galoth. “Study of Chromosome.” Genetics Fundamentals Notes. Singapore: Springer Nature Singapore, 2022. 239-298.

70. Morris, Christine M. “Chronic myeloid leukemia: cytogenetic methods and applications for Diagnosis and treatment.” *Cancer Cytogenetics: Methods and Protocols* (2011): 33-61.
71. Weckselblatt, Brooke, and M. Katharine Rudd. “Human structural variation: mechanisms of Chromosome rearrangements.” *Trends in Genetics* 31.10 (2015): 587-599.
72. Goswami, Deepti, and Gerard S. Conway. “Premature ovarian failure.” *Human reproduction Update* 11.4 (2005): 391-410.
73. Bouwels, Rik. *The Potential Impact of Chromosomal Instability and Aneuploidy on cell-cell Competition during Colorectal Cancer development*. MS thesis. 2024.
74. Weinberg, Robert A. “How cancer arises.” *Scientific American* 275.3 (1996): 62-70.

75. Kang, Zhi-Jie, et al. "The Philadelphia chromosome in leukemogenesis." Chinese journal of Cancer 35 (2016): 1-15.
76. Ogden, Angela, et al. "Multi-institutional study of nuclear KIFC1 as a biomarker of poor Prognosis in African American women with triple-negative breast cancer." Scientific reports 7.1 (2017): 42289.
77. Panno, Joseph. Cancer: The role of genes, lifestyle, and environment. Infobase Publishing, 2005.
78. Tijhuis, Andréa E., Sarah C. Johnson, and Sarah E. McClelland. "The emerging links between Chromosomal instability (CIN), metastasis, inflammation and tumour immunity." Molecular Cytogenetics 12.1 (2019): 17.
79. Ashwell, Susan, and Sonya Zabludoff. "DNA damage detection and repair

pathways—Recent advances with inhibitors of checkpoint kinases in cancer therapy.” *Clinical Cancer Research* 14.13 (2008): 4032-4037.

80. Gardner, RJ M Kinlay, Grant R. Sutherland, and Lisa G. Shaffer. *Chromosome abnormalities and genetic counseling*. No. 61. OUP USA, 2012.

81. Logsdon, Glennis A., Mitchell R. Vollger, and Evan E. Eichler. “Long-read human genome Sequencing and its applications.” *Nature Reviews Genetics* 21.10 (2020): 597-614.

82. McCarthy, Jeanette J., Howard L. McLeod, and Geoffrey S. Ginsburg. “Genomic medicine: A decade of successes, challenges, and opportunities.” *Science translational medicine* 5.189 (2013): 189sr4-189sr4.

83. Trichopoulos, Dimitrios, Frederick P. Li, and David J. Hunter. "What causes cancer?." *Scientific American* 275.3 (1996): 80-87
84. Paraskevaidis, Evangelos, et al. "The role of HPV DNA testing in the follow-up period after treatment for CIN: a systematic review of the literature." *Cancer treatment reviews* 30.2 (2004): 205-211
85. Heng, Henry H., et al. "Chromosomal instability (CIN): what it is and why it is crucial to cancer evolution." *Cancer and Metastasis Reviews* 32 (2013): 325-340.