Biomathematics - Video course

COURSE OUTLINE

Graphs and functions, Derivative of a function, Techniques of differentiation Differentiation and its application in Biology, Finding maxima, minima, Plotting functions, Integrals, Techniques of Integration

Scalars and vectors. Force, Concentration gradient, Polar coordinates

Differential equations, Nernst Equation, Diffusion Equation, Mean-square displacement, Einstein's relation

Probability and Statistics: Mean and variance, Distribution functions: Normal Distribution, Uniform distribution, Poisson distributions, Knudson's analysis, Wright-Fisher model, Fitting a function to experimental data

Fourier Series, Fourier transform, Z-transform, Discussion of the use of Fourier transformation in X-ray crystallography, and other areas in biology.

Modeling biological problems: Statistical thermodynamics,
Flexible proteins--size and conformations, Polymerization dynamics, Molecular motor motion, Bending and looping of DNA, Protein organization along DNA

COURSE DETAILS

Module	Topics
	Lecture 1: Introduction
	Keywords: Mathematics as a language, Need of learning mathematics, Applications of mathematics in Blology
	Lecture 2: Graphs and functions - I
	Keywords: Linear function, Quadratic function, Exponential function
	Lecture 3: Graphs and functions - II
	Keywords: Periodic functions, Combination of simple functions, Examples from Biology
	Lecture 4: Functions and derivatives
	Keywords: Logarithmic function, Slope of curves, Idea of derivative

NP-TEL

NPTEL

http://nptel.iitm.ac.in

Biotechnology

Additional Reading:

1. Biological Physics, Philip Nelson, W. H. Freeman, 1st edition (2007)
2. Mechanics of Motor Proteins and the Cytoskeleton, J. Howard, Sinauer Associates; New edition (2001)
3. Calculus and Analytic Geometry, Georege Thomas, Ross Finney Addison Wesley, 9 edition (1995)

Coordinators:

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Module- I: Calculus	**Lecture 5: Calculation of derivatives**	
	Keywords: Derivatives of simple functions, Derivative of exponential function, Derivative of sum of two functions	
	Lecture 6: Differentiation and its application in Biology - I	
	Keywords: Product rule in differentiation, Derivatives of Sine and Cosine functions, Plotting derivatives, Differential calculus to understand actin polymerization	
	Lecture 7 : Differentiation and its application in Biology - II	
	Keywords: Enthalpy and Entropy of a chemical reaction, Growth curve, Idea of curvature	
	Lecture 8 : Differentiation and its application in Biology - III	
	Keywords: Curvature, Free energy, Energy of spring-like protein, Maxima and Minima of a function	
	Lecture 9: Differentiation and its application in Biology - IV	
	Keywords: Force and energy, DNA unzipping, Plotting mathematical functions	
	Lecture 10: Integration -I	
	Keywords: Indefinite integrals, integration of simple functions, Integral as “anti-derivative”	
	Lecture 11: Integration - II	
	Keywords: Definite integrals, Integral as area under a curve, Integration by parts, Finding derivative and integral given a set of data points	
	Lecture: 12: Differential equations-I	

Module: II: Differential Equations	Keywords: Simple differential equations, First order differential equations, Examples: Polymerizing and depolymerizing filaments, Cell growth
	Lecture : 13: Differential equations - II
	Keywords: Concentration gradient, Second order differential equations. Motion of an object under external force : Newton's equations
Module III: Vectors	**Lecture 14: Vectors - I**
	Keywords: Physical quantities like position and force as vectors, Attracting and repelling charges, Vector addition
	Lecture 15: Vectors - II
	Keywords: Calculation of forces in a system of charges, Calculation of magnitude and direction of a vector, Unit vectors, Calculation of resultant force
	Lecture 16: Vectors - III
	Keywords: Dot product and cross product, Polar coordinate system, Gradient of a scalar
Module IV: Applications of calculus and vector algebra in biology	**Lecture 17: Nernst equation**
	Keywords: Potential difference across a membrane, Flow of ions due to diffusion, Flow of ions due to electrostatic interactions
	Lecture 18: Diffusion-I : Diffusion equation
	Keywords: Continuity equation, Diffusion equation, Mean-square position
	Lecture 19: Diffusion - II: Mean-square displacement
	Keywords: Mean-square displacement, Derivation of mean-square displacement, Mean-square distance scaling with time, Diffusion timescale
	Lecture 20: Diffusion-III : Einstein's relation

	Keywords: Mean displacement, Diffusion coefficient, Einstein's relation, Diffusion under external field
Module V: Probability and statistics in Biology	**Lecture 21 : Statistics : Mean and variance**
	Keywords: Introduction to statistics, Mean/Average, Variance, Standard deviation
	Lecture 22: Statistics: Distribution function
	Keywords: Introduction to distribution functions, Normal distribution, Examples from biology: End-to-end vector distribution of DNA, Concentration distribution
	Lecture 23 : Understanding Normal distribution
	Keywords: Gaussian function, Peak as average of normal distribution, Width of a Gaussian and standard deviation
	Lecture 24: Fitting a function to experimental data
	Keywords: Linear fit, Least-square fit, Errors
	Lecture 25 : Size of a flexible protein: Simplest model
	Keywords: Flexible protein chain, End-to-end distance, End-to-end distance scaling with polymer length, Random walk, Normal distribution, Exponential distribution
	Lecture 26: Uniform and Poisson distributions; Knudson's analysis
	Keywords: Uniform distribution, Poisson distribution, Knudson's analysis of retinoblastoma patients, Poisson statistics and tumor
	Lecture 27: Fourier Series-I
	Keywords: Introduction to Fourier series, Fourier coefficients, Calculation of Fourier series for simple functions, Sum of periodic functions

Module VI : Fourier series and Fourier transform	**Lecture 28: Fourier Series-II**	
	Keywords: Fourier coefficients with more examples, Calculation of Fourier series for square-wave-like function, Learning Fourier series by plotting functions	
	Lecture 29: Fourier transform	
	Keywords: Introduction to Fourier transform, Fourier space, Inverse Fourier transform, Application of Fourier transform: X-ray crystallography, structure studies of proteins, Z-transform	
Module VII: Mathematical models in biology	**Lecture 30: Master equation: Polymerization dynamics, Molecular motor motion**	
	Keywords: Simple model for polymerization depolymerization dynamics, Simple model for molecular motor motion, Biased walk, Growth velocity of polymerizing filaments, Master equation, Solving master equation	
	Lecture 31: Evolution: Simplest model	
	Keywords: Wright-Fisher model, Simplest model in population genetics/evolution, Binomial distribution, Evolution	
Module VIII: Tutorials	**Lecture 32: Tutorial - I**	
	Keywords: Microtubule dynamics, Dynamic instability, application of functions and derivatives, Enzyme kinetics	
	Lecture 33: Tutorial-II	
	Keywords: Vectors, Pulling chromosome, Diffusion coefficient, Integral of a Gaussian function	
	Lecture 34: Temperature, Energy and Entropy	
	Keywords: Definition of temperature, Definition of internal energy, Definition of entropy, Calculation of entropy, entropy of a flexible protein	
	Lecture 35: Partition function, Free energy	

	Keywords: Definitions, Calculation of partition function, Calculation of Free energy, Thermal Equilibrium, Bending of DNA
	Lecture 36: Bending fluctuations of DNA and spring-like proteins
	Keywords: Worm-like chain model, Partition function, Gibbs free energy
Module IX : Statistical thermodynamics of biological systems	**Lecture 37: Force-extension and looping of DNA**
	Keywords: Force extension relation of single stranded DNA, Persistence length, Looping of DNA,
	Lecture 38: Thermodynamics of protein organization along DNA
	Keywords: Proteins binding on DNA, Calculation of energy, entropy and free energy, Thought-experiment on DNA melting
	Lecture 39: Learning mathematics with the help of a computer
	Keywords: Plotting functions using computer, gnuplot demonstration, numerical calculations, Interpolation

References:

- Mathematics for Biological Scientists, M. Aitken, B. Broadhursts, S. Haldky, Garland Science (2009)
- Introduction to Mathematics for Life Scientists, E. Batschelet, Springer Verlag, 3rd edition (2003)
- Calculus for Life Sciences, R. De Sapio, W. H. Freeman and Co. (1976)
- Physical Biology of the Cell, R Phillips, J Kondev, J. Theriot, Garland Science (2009)
- Random Walks in Biology, H. C. Berg, Princeton university press (1993)