4. Fish Genetics and Breeding

Major Courses				
A	**Code**	**Course Title**	**Credit**	**20 Credits**
1	**FGB 501***	PRINCIPLES OF GENETICS AND BREEDING*	**2+1**	
2	**FGB 502***	POPULATION AND QUANTITATIVE GENETICS*	**2+2**	
3	**FGB 503***	PRINCIPLES OF SELECTION AND SELECTION METHODS*	**2+1**	
4	**FGB 504***	FISH BREEDING PLANS*	**2+1**	
5	**FGB 505**	CONSERVATION OF FISH GENETIC RESOURCES	**2+1**	
6	**FGB 506**	BIOINFORMATICS AND COMPUTER APPLICATIONS IN FISH GENETICS	**0+2**	
7	**FGB 507**	MOLECULAR AND CYTOGENETICS@	**2+1**	
8	**FGB 508**	CELL AND TISSUE CULTURE#@	**1+1**	
9	**FGB 509**	MOLECULAR BREEDING	**1+1**	
10	**FGB 510**	MICROBIAL GENETICS#@	**2+0**	
B	**Minor Courses** (From the subjects closely related to a students major subject)			**8 Credits**
1	FBT 501	Fundamentals of Molecular Biology	2+1	
2	AQC 504	Aquaculture Policy and Planning	1+1	
3	AQC 512	Commercial Ornamental Fish Breeding and Culture	1+1	
4	FBT 509	Molecular Markers	2+1	
C		**Supporting courses** (The subject not related to the major subject. It could be any subject considered relevant for students research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence)	6	**6 Credits**
D		**Common courses** (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills		**5 credits**

		3. Intellectual Property and its management in Agriculture 4. Basic concepts in Laboratory Techniques 5. Agricultural Research, Research ethics and Rural Development Programmes (Some of these courses are already in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platforms. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS).		
	Total Course Work Credits			**39 Credits**
E	**MASTERS' SEMINAR**			**1 Credit**
1	FGB 591	Master's Seminar	0+1	
F	**MASTERS' THESIS RESEARCH**			**30 Credits**
1	FGB 599	Master's Research (Semester III)	0+15	
2	FGB 599	Master's Research (Semester IV)	0+15	
	Total M.F.Sc. Program Credit Hours			**70 Credits**

*Major compulsory courses

M. F. Sc. (Fish Genetics and Breeding)

Course Content

FGB-501 PRINCIPLES OF GENETICS AND BREEDING 2+1

Objective	**To understand the basic principles of genetics and breeding and their application to fisheries management and aquaculture**
Theory	
Unit-I	Historical development of genetics and breeding; Aim and scope of genetics and breeding; Domestication; Society and Genetics-Ethical issues. Basic statistical parameters-Probability concepts; Mean, Variance, Coefficient of variation, Correlation, Regression and Analysis of Variance
Unit-II	Cell structure, cell division and physical basis of heredity; Mendel's Principles: Scope, Limitation Modifications to Mendel's ratios: Multiple alleles, Epistasis; Chromosomaltheory of inheritance; Genetic variation: Causes and measurement;

	Linkage and crossing over, Recombination, Interference, Linkage disequilibrium
Unit-III	Modern concept of gene; DNA as genetic material, Replication of DNA; Genetic code and protein synthesis, Transfer and regulation of genetic information Introduction to bioinformatics in fish genetics and breeding, Fish Genome: Zebrafish genome, Fish as genetic model
Unit-IV	Cytogenetics: Cytogenetics and evolution; Karyotyping and chromosome banding; Genetic basis of sex determination; Sex-linked, Sex-limited, and Sex-influenced traits, Y-linked inheritance; Chromosome manipulation: Ploidy induction, Sex reversal, Gynogenesis and Androgenesis; Chromosomal aberrations; Mutations- Natural and Induced, Mutagens
Unit-V	Basic concepts of Population Genetics: Individual vs population; Gene and Genotype frequency Hardy-Weinberg Principles and factors affecting them; Mutation; Fate of mutant allele in the population; Genetic drift; Concept of inbreeding and its management; Application of population genetics in fish resource conservation, preservation of gametes
Unit-VI	Basic Concepts of Quantitative Genetics; Polygenic inheritance; Basis of genetic selection: Qualitative vs quantitative traits; Pleiotropy; Penetrance; Natural Vs Artificial Selection, Aim of genetic selection and breeding,present status of selective breeding in aquaculture; Economic traits of fish Pedigree and its importance in fish breeding; Methods and aid to genetic selection Application of selection for performance improvement Cross breeding and Hybridization.
Practical	
	Probability in genetics Exercises on Mendel's principles, Multiple alleles, Epistasis, Linkage and crossing over Exercises on Hardy-Weinberg principles Estimation of gene and genotype frequencies Karyotyping; Nucleic Acid isolation Quantification of Inbreeding; Estimation of kinship coefficient Record keeping in fish breeding Estimation of genetic parameters
Suggested Readings	1. Kirpichnikov, V.S. 1981. *Genetic Basis of Fish Selection*. Springer-Verlag

	2. Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House. 3. Lutz CG. 2003. *Practical Genetics for Aquaculture*. Wiley-Blackwell. 4. Lynch M & Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland. 5. Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman & Hall. 6. Snustad DP & Simmons MJ. 1999. *Principles of Genetics*. 2nd Ed. John Wiley & Sons. 7. Stansfield WD. 1991. *Theory and Problems of Genetics*. McGraw-Hill. 8. Tave D. 1993. *Genetics for Fish Hatchery Managers*. 2nd Ed. Chapman & Hall. 9. Gjedrem, Trygve et al., 2005. Selection and Breeding Programs in Aquaculture Springer 10. KorOldenbroek en Liesbeth van der Waaij. 2014. Textbook Animal breeding and genetics. Wageningen University and Research Centre, the Netherlands https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf

FGB-502 POPULATION AND QUANTITATIVE GENETICS (2+2)

Objective	**Understanding the concepts of genetic structure of the population and inheritance of quantitative traits**
Theory	
Unit-I	Historical developments; Review of basic concepts of genetics and statistics; Scope and applications Biometrical techniques: Introduction to matrix algebra, Determinants, ANOVA, Regression and Correlations Basic concepts of General Linear Mixed Models (GLMM)
Unit-II	Definition of population, Individual vs. population, quantitative vs. qualitative characters Genetic structure of random mating populations. Polygenic inheritance: Limitation of single gene model; Polygenes and major genes; Polygenic model-importance and limitations; Polygenic segregation and linkage
Unit-III	Hardy -Weinberg principles: Test, application and properties of equilibrium populations Systematic and dispersive forces changing gene and genotype frequencies, Concept of Mutation, Balance between mutation and selection Genetic bottleneck: genetic drift, drift equilibrium, Effect on population structure Intensity of selection, Fisher's theorem of natural selection; Wahlund effect

Unit-IV	Coefficient of genetic differentiation – F_{ST}, R_{ST}, Q_{ST}, G_{ST} - their relative merits and demerits, Genetic similarity, distance and population divergence. Null alleles Path coefficient: theory, analysis and applications. Basis of relationships: Independent and correlated causes Idealized population and its properties, Effective population size. Concept of inbreeding- Calculating coefficient of kinship, relationship, inbreeding and population size; types and methods of estimation and consequences- Change of mean and variance Mechanisms of evolution and speciation; Delineation of species and/or stocks
Unit-V	Quantitative variation: Gene effects; Mode of inheritance and continuous variation; Population mean; Components of phenotypic value, Genotypic value, Average effect of gene and gene substitution Estimation tools for population genetic parameters – Variance component estimation with complex pedigree Genetic parameters: heritability- Concept of heritability, Effective heritability, different methods of estimation, variance of heritability, properties and applications of heritability; repeatability, Maternal effects; Correlation between traits- Composition of genetic and phenotypic covariance genetic, phenotypic and environment correlations and their standard errors, Concept of co-heritability
Unit-VI	Breeding value: Biometrical relationship among relatives; Estimating fixed factors and predicting random effects-BLUE and BLUP; Models for EBV Selection: Aids and methods; genetic gain and correlated response; Recurrent and reciprocal recurrent selection Heterosis: Theories and estimation, Combining ability-GCA, SCA; Utilization of non-additive genetic variance Genomics and Phenomics
Practical	
	Exercise on various statistical procedures and matrix algebra- Components of Variance, Covariance, Correlation and Regression, ANOVA in genetic parameter estimation Estimation of gene and genotype frequencies and factors affecting them, Equilibrium in sex linked genes Genetic stock structure analysis with dominant and co-dominant markers- Type I and Type II markers; Pedigree construction through Molecular marker information Path coefficient Estimation of effective population size, Rate of inbreeding, inbreeding co-efficient, Estimation of Heritability and Repeatability and their accuracies; Building of pedigree files and construction of relationship matrix and its inverse; Estimation of breeding values-EBV, BLUE and BLUP Genetic gain

Suggested Readings	**1**. Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag. 2. Falconer DS &Markay TFC. 1996. *An Introduction to QuantitativeGenetics*. 4th Ed. Addison Wesley Longman. 3. Li CC. 1955. *Population Genetics*. University of Chicago Press. 4. Lynch M & Walsh B. 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer, Sunderland. 5. Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press. 6. Turner HN & Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell University Press. 7. Hartl D. 1988. *A Primer in Population Genetics*. Sunderland 8. Hartl D & Clarke AG. 2007. *Principles of Population Genetics*. 4th Ed. Sunderland 9. https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf 10. https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-503 PRINCIPLES OF SELECTION AND SELECTION METHODS (2+1)

Objective	**To learn the application of genetic tools for genetic improvement of aquatic species**
Unit-I	Genetic Selection and breeding: Scope, application, role of genetics in fish selection and breeding National and International scenario of selective breeding programmes in aquaculture
Unit-II	Selection: Basis of selection Introduction to variance components Estimation of selection differential, intensity of selection, response to selection Identification of animals with high genetic merit Estimation of breeding values- variance and accuracy of predicted breeding value; Various sources of information- Individual, information from relatives; Least squares and BLUP methods; Accuracy of selection
Unit-III	Combined selection: combined selection Selection index-selection objective and criterion, selection criterion coefficients Methods of selection Realized heritability, repeatability, genetic, phenotypic and environmental correlations.
Unit-IV	Factors affecting rate of genetic improvement

	Short term response to selection- Variance in response-Bidirectional selection, Selection limits Renewed selection gain Threshold characters- Heritability of threshold traits, genetic correlation among threshold traits, selection for threshold traits Scale effects
Unit-V	Formulation of breeding plans: Stock improvement plans for different population sizes and environments, Control population and experimental design Development of new strains/synthetic population; Crossbreeding and hybridization. Domestication and inadvertent selection Selection and mating designs for select traits: Mating systems and genetic consequences; Small stock and inbreeding effects, Inbreeding depression: causes and methods to overcome; Out breeding: crossbreeding, utilization of heterotic effects Selection and mating designs for growth, disease resistance, color enhancement Genotype x Environment interaction and its role in fish/shellfish breeding
Unit-VI	Major genes and QTLs- Major and minor genes, Tests for detecting major genes Application of markers in selection programmes, status and their relevance; QTL and its application in selection Marker Assisted Selection in Fisheries; Genomic selection.
Practical	
	Estimation of genetic parameters: heritability, repeatability and genetic correlation; Estimation of phenotypic and environmental correlations Estimation of Breeding Values from various sources of information and their accuracies Construction of selection indices Designing and conducting challenge test for disease resistance. Selection: basis of selection, genetic gain Response to selection and factors affecting response Aids to selection; Methods of selection QTL and MAS
Suggested Readings	1. Cameron ND. 1997. *Selection Indices and Prediction of Genetic Merit in Animal Breeding*. CABI. 2. Doolittle DP. 1987. *Population Genetics: Basic Principles*. Springer-Verlag. 3. Falconer DS & Mackay TFC. 1996. *An Introduction to Quantitative Genetics*. 4th Ed. Addison Wesley Longman. 4. KorOldenbroek en Liesbeth van der Waaij. 2014. Textbook Animal breeding and genetics. Wageningen University and Research Centre, the Netherlands 5. Lynch M & Walsh B. 1997 *Genetics and Analysis of Quantitative Traits*. Sinauer, underland. 6. Pirchner F. 1983. *Population Genetics in Animal Breeding*. Plenum Press.

	7. Turner HN & Young SSY. 1969. *Quantitative Genetics in Sheep Breeding*. Cornell university Press. 8. Gjedrem, Trygve et al., 2005. Selection and Breeding Programs in Aquaculture Springer 9. https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf 10.https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-504 FISH BREEDING PLANS (2+1)

Objective	**To learn the applications of genetic techniques for stock improvement**
Theory	
Unit-I	Historical development of fish breeding and domestication Current status of aquaculture in world and India Maintaining pedigree-Physical and molecular tagging and maintaining breeding records
Unit-II	Economic traits in cultured species-Performance- Growth, Disease resistance, productive &reproductive traits, recapture frequency, behavior, quality traits and their inheritance Recording economic traits Study of growth curves and their components Influence of non-genetic factors on economic traits
Unit-III	Formation of base population, Designing mating plans Effect of breeding programme on genetic diversity of farmed animals Present status of breeding Cross breeding in aquaculture; Broodstock management Inbreeding depression and heterosisin various economic characters Role of Breeders' associations in national breeding programmes Fish breeding guidelines, Policies, programs and economic analyses of breeding programmes- their present status in India and world, prospectus and challenges.
Unit-IV	Reproductive cycle, Factors affecting sexual maturation, Adapatability and reproduction, Age at maturity, Gonadal development stages in fin/shellfish and levels of hormonal intervention; Sex determination, Cryopreservation of gametes, Live feed development for larvae, Larval feeding and maintenance, Packaging and transport of fish; Nursery systems and their operation; Biosecurity
Unit-V	Application of recent technologies in stock improvement Biosafety issues involved with genetically modified organisms Release and registration of new varieties

	Quality seed: classes, production practices and maintenance of pure seed, Seed purity standards; Seed quality and fish seed certification.
Unit-VI	Shellfish breeding: Reproductive cycle of the shellfish; controlled mating of the shellfish; Economic traits and their recording. Ornamental fish breeding: Introduction to ornamentation and their inheritance Selection and mating systems, inbred strains, transgenic strains, production of gene knock-out fish, Genetic control and monitoring, Record keeping and ethics
Practical	Tagging methods Construction of growth curves Record keeping of stock; Standardization of the performance records for genetic parameters estimations Breeding plan and design of breeding programme from successful case studies Morphometric analysis- Truss analysis Practical on synchronization of spawning, Closed lifecycle and controlled mating-Hormone induced ovulation; Collection of fish gametes, Assessing gamete quality Cryopreservation
Suggested Readings	1. Hoar WS & Randall DJ.1988. *Fish Physiology*. Academic Press. 2. Kinghorn BP. 1981. *Quantitative Genetics in Fish Breeding*. University of Edinburgh. 3. Purdom CE. 1993. *Genetics and Fish Breeding*. Chapman & Hall. 4. Thomas PC, Rath SC &Mohapatra KD. 2003. Breeding and Seed Production of Finfish and Shellfish. Daya Publ. House. 5. Weatherely AH & Gill HS. 1988. *The Biology of Fish Growth*. Blackwell Synergy. 6.Gjedrem, Trygve et al., 2005. Selection and Breeding Programs in Aquaculture Springer 7. Rath, R.K., 2018. *Freshwater aquaculture*. Scientific Publishers. 8. Chattopadhyay, N.R., 2016. *Induced fish breeding: A practical guide for hatcheries*. Academic Press. 9. Lee, C.S. and Donaldson, E.M. eds., 2012. *Reproductive biotechnology in finfish aquaculture*. Elsevier. 10. https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf 11. https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-505 CONSERVATION OF FISH GENETIC RESOURCES (2+1)

Objective	**To impart knowledge on application of genetic principles in conservation and management of aquatic resources.**
Theory	
Unit-I	Fish genetic resources: Sample survey and distribution Threatened aquatic species of India and world Assessing threats to species and populations Conflicts between nature conservation and other goals of the society
Unit-II	Evolutionary Genetics- Genetic diversity, importance, influencing factors, characterizing genetic diversity, evolution in large and small population, Maintenance of genetic diversity Conservation and preservation of aquatic species: Effect of population size-loss of genetic diversity in small population, inbreeding, population fragmentation, Issues and strategies Risk status/population viability analysis and classification Breeding strategies of threatened species for restocking and live gene bank
Unit-III	Importance of mutation, migration and their interaction with selection in conservation Application of molecular genetic tools for management of small population for conservation
Unit-IV	Gene bank: Concepts, objectives, resources, uses Institutes and Societies associated with conservation Impact of inbreeding on genetic diversity and conservation; Evolutionary potential and heritability; Genetics and management of wild and captive populations Introduction, domestication and acclimatization Genetic management for reintroduction; *In-situ* and *ex-situ* conservation; gene pool concept - primary, secondary and tertiary gene pool, and gene introgression Cryopreservation of sperm, eggs and embryos.
Unit-V	Effective population size and population structure; Factors threatening indigenous species; IPR issues of genetic resources; Regulations regarding introduction of exotic germplasm; Export import rules and regulations on conservation of aquatic genetic resources; Fish quarantine – status, procedures, scope and significance Convention on Biodiversity and National Biodiversity Authority of India
Unit-VI	Taxonomy and related issues, DNA barcoding, Characterization and identification of stock; Identification of farm escapees, interaction between farmed and wild population Application of nanobiosensor for tracking of fish Genomics in Conservation: Effect of climatic change on biodiversity.
Practical	Tagging methods for population Estimation of gene and genotypic frequencies Estimation of genetic diversity and relatedness using morphometric andmolecular information

	Application of molecular genetic markers for estimation of effective population size, rate of inbreeding and genetic bottleneck Analysis of genetic variance in population Morphometric analysis of stocks Visit to Gene Bank/National/Regional Research Centres Studies on Domestic and international quarantine process; its weaknesses and measures for its strengthening Case studies on rescue and release of animals
Suggested Readings	1. Allendorf FW. 2007. *Conservation and the Genetics of Populations*. Blackwell. 2. Cloud JG &Thorgaard GH. 1993. *Genetic Conservation of Salmonid Fishes*. NATO ASI Series, Life Sciences, Springer. 3. Frankham R, Ballou JD & Briscoe DA. 2004. *A Primer of Conservation Genetics*. Cambridge University Press. 4. Frankham R. 1995. *Introduction to Conservation Genetics.* Annual Reviews of Genetics. 5. Hartl D. 1988. *A Primer in Population Genetics*. Sunderland. 6.Bruce Walsh and Michael Lynch, 2018.Evolution and Selection of Quantitative Traits. Oxford University Press in the UK 7. Roff, Derek A. 2012. *Evolutionary quantitative genetics*. Springer Science & Business Media. 8. http://agtr.ilri.cgiar.org/overview 9. https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-506 BIOINFORMATICS AND COMPUTER APPLICATIONS IN FISH GENETICS (0+2)

Objective	To learn the application of information technology and software packages for the Fish Genetics and Breeding studies
Practical	
Unit-I	File Transfer Protocols; Work stations Application of spreadsheets in maintaining fish breeding records and breeding data management Fish breeding data bases Data input, import, export, modification; Data cleaning, manipulation and transformations; data normalization Graphical analysis and representation of breeding data
Unit-II	Introduction to basic matrix algebra-Definition, Addition, multiplication, Determinants Inverse of matrix

Unit-III	Usage of various computer packages for genetic analyses: SAS, R, AsReml and others. Analysis of variance, Variance component estimations Estimation of genetic parameters; Inbreeding estimation
Unit-IV	Software for molecular genetics data analysis (SAS Genetics, SAS Genomics, R) Estimation of population parameters Estimation of 'F' Statistics
Unit-V	Introduction to Bioinformatics and various operating systems employed Exposure to various open source online bioinformatics tools and applications Use of Perl and R-Bio conductor packages Introduction to Bioinformatics databases Information retrieval from various sequence and structure databases and mock sequence submission Database searching, Sequence formats and alignments; BLAST, Conversion and handling of various sequence formats, Usage of online sequence alignment tools.
Unit-VI	Sequence analysis; Annotation, Sequence conversion and translation, Sequence comparison, Phylogenetic analysis. Protein structure analysis and its analysis; analysis of amino acids sequence NGS data formats and data cleaning Use of bioinformatics tools for identifying QTL and selection of elite germplasm
Suggested Readings	1. Attwood TK & Smith DJP. 1999. *Introduction to Bioinformatics*. Addison Wesley Longman. 2. Brown SM. 2000. *Bioinformatics: A Biologist's Guide to Biocomputing and the Internet*. Eaton Publ. 3. Lesk AM. 2008**.** *Introduction to Bioinformatics.* Oxford University Press. 4. Mount DW. 2001. *Bioinformatics: Sequence and Genome Analysis*. ColdSpring Harbor Press. 5. Rashidi HH & Buehler LK. 2005. *Bioinformatics Basics: Applications in Biological Sciences and Medicine*. CRC Press. 6. Cody RP & Smith JF. 1997. *Applied Statistics and SAS Programming Language*. Elsevier**.** 7. Littell RC, Milliken GA, Stroup WW &Wolfinger RD. 1996. *SAS System for Mixed Models*. SAS Institute. 8. Saxton AM. 2004. *Genetic Analysis of Complex Traits Using SAS*. SAS Publ. 9. Isik, Fikret, James Holland, and Christian Maltecca.2017. Genetic data analysis for plant and animal breeding. New York: Springer. 10.https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf 11. https://www.jmp.com/en_us/academic/jmpg-course-materials.html

	Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-507 MOLECULAR AND CYTOGENETICS (2+1)

Objective	**To impart knowledge on different tools of molecular and cytogenetic**
Theory	
Unit-I	Introduction, Historical background Importance, Chromosome theory of inheritance: chromosomal models and their ultra-structure Chromosomal movements and position effect Cytogenetic and evolution
Unit-II	DNA and RNA as genetic material; Chemistry and structure of DNA Fine structure of gene, Split genes, Pseudogenes, Overlapping genes and Multigene families Mechanisms of DNA replication Extra Chromosomal Inheritance / Cytoplasmic Inheritance: Mitochondrial DNA
Unit-III	Biochemical markers: Allozyme polymorphism and its application in estimating population genetic parameters Genetic basis of immunity
Unit-IV	Molecular markers: RAPD, RFLP, AFLP, EST, SNP, Minisatellites and Microsatellites and application in population genetic analysis and gene mapping FISH – principle and application Maternally and paternally inherited genetic markers Molecular pedigree Major genes, Poly genes and QTLS Application of molecular markers in genetic selection-QTL and MAS, Association studies, Genomic selection
Unit-V	Genetics of Sex determination and differentiation: Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, production of monosex population Sex chromatin and Lyon's hypothesis; Chromosome numbers in fish and karyotyping, Chromosome banding techniques Molecular Cytogenetics: Fluroscence In Situ Hybridisation (FISH) Application of nanotechnology in chromosome and genome mapping Mitochondria and Y chromosome
Unit-VI	Genotoxicity and mutagenicity Chromosomal aberrations; single cell gel electrophoresis, MNT, SCE ; Genetic and evolutionary implications
Practical	
	Preparation of chromosome spreads; Karyotyping; Banding techniques; MNT, SCE, Comet Assay.

	Genomic DNA isolation from prokaryotes and eukaryotes Isolation of RNA and RT-PCR, Agarose gel electrophoresis of DNA and RNA PCR, primer designing, PCR-RFLP, extraction of DNA from agarose gels Biochemical markers and Molecular markers Interpretation of gels and data analysis using various software DNA sequence polymorphism and related software for alignment and analysis
Suggested Readings	1. Lakra WS, Abidi SAH, Mukherjee SC &Ayyappan S. 2004. *Fisheries Biotechnology*. Narendra Publ. House. 2. Pisano E. 2007. *Fish Cytogenetics*. Science Publ. 3. Reddy PVGK, Ayyappan S, Thampy DM & Krishna G. 2005. *FishGenetics and Biotechnology*. ICAR. 4. Caetano-Anolles G &Gresshoff PM. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH. 5. Pasteur N, Pasteur G, Bonhomme F, Catalan J & Britton-Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood. 6. Sambrook J &Russel WD. 1989. *Molecular Cloning: A Laboratory Manual*. Vols. I-III. Cold Spring Harbor Laboratory Press Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB-508 CELL AND TISSUE CULTURE (1+1)

Objective	**To impart knowledge on cell and tissue culture techniques and their application in gene banking, genetic characterization and health management.**
Theory	
Unit-I	Introduction: Structure and Organization of animal cell; Equipment and materials for animal cell culture technology Cell lines and media: Primary and established cell line cultures; media supplements – their metabolic functions; serum and protein free defined media and their application
Unit-II	Cell culture: Basic techniques of cell culture in vitro; development of primary cultures, cell separation, maintenance of cell lines; biology of cultured cells, transformation and differentiation of cell cultures Characterization of cell lines: Measurement of viability and cytotoxicity assays; measuring parameters of growth; karyotyping, isozyme assays, cryopreservation, assessment of contaminants
Unit-III	Cell cloning: Micromanipulation, cell transformation, application of fish cell culture, 3D cell culture, scaling-up of cell culture Cell hybridization: Somatic cell fusion, hybridoma technology, Production and Application of monoclonal antibodies
Unit-IV	Stem cell culture and its application

	Bio-products from cell culture, cryopreservation of embryos and cells
Practical	
	Principles of sterile techniques and cell propagation Preparation of different cell culture media Primary cell culture techniques; Establishing cell lines: isolation, characterization identification of cell lines Pure culture techniques; Maintenance and preservation of cell lines Propagation of cells in suspension cultures Hybridoma technology: strategy and techniques Production of monoclonal antibodies Cryopreservation of cell lines
Suggested Readings	1. Barnes D and Mathur PJ. 1998. *Methods in Cell Biology*. Vol. 57. *Animal Cell Culture Methods*. Academic Press. 2. Basega R. (Ed.). 1989. *Cell Growth and Division: A Practical Approach*.IRL Press. 3. Butler M and Dawson M. (Ed.). 1992. *Cell Culture*. Bios Scientific Publ. 4. Clynes M. 1998. *Animal Cell Culture Techniques*. Springer. 5. Freshney I. 1994. *Culture of Animal Cells: A Manual of Basic Techniques*. 4th Ed. Wiley-Liss. 6. Harrison A.M., Rae FI and Harris A. 1997. *General Techniques of Cell Culture*. Cambridge University Press. 7. Lan F.R. 1994. *Culture of Animal Cells*. 3rd Ed. Wiley-Liss. 8. Masters RW. 2000. *Animal Cell Culture-Practical Approach*. Oxford University Press

FGB-509 MOLECULAR BREEDING (1+1)

Objective	To apply basic concepts of molecular genetics in fish breeding
Theory	
Unit-I	Introduction to Molecular Breeding; Molecular mechanism of genetic recombination. Molecular taxonomy and its application in Fisheries; Phylogenetics and its application Genetics of Sex determination: Genotypic sex determination (GSD); Environmental Sex determination (ESD); Sex manipulation, production of monosex population
Unit-II	Single genes in fish breeding: Mapping and Identifying single genes; types of DNA sequence responsible for alterations to create single gene effect QTL and MAS identification; marker assisted selection with markers in linkage disequilibrium with QTL Molecular pedigree Assigning
Unit-III	Major genes, Poly genes and QTLS- Tests for detecting major genes, complex segregation analysis Genetic maps and candidate genes

	Genome-wide association studies (GWAS) in pedigreed population- Methods and tools for GWAS
Unit-IV	Introduction to genomic selection; Methodologies for genomic selection; Estimation of Genomic breeding value, Factors affecting the accuracy of genomic selection Genomic selection with low marker density; Genomic selection across populations and strains Re-estimation of the chromosome segments Designing breeding programs with genomic information
Practical	
	LD Analysis Molecular pedigree construction Power of association studies; Building the IDB matrix from linkage disequilibrium information; marker assisted selection with linkage disequilibrium Genomic Relationships and GBLUP; Realized Genomic Relationships; Calculation of G Matrices; Genomic BLUP;Genomic selection using BLUP; Genomic selection using a Bayesian approach; Bayesian Approach using a prior for chromosome segment variances with a large weight at zero (Bayesian)
Suggested Readings	1. Caetano-Anolles G. and Gresshoff, P.M. 1998. *DNA Markers: Protocols, Applications and Overviews*. Wiley-VCH. 2. Lehninger LA, Nelson DL & Cox MM. 2008. *Principles of Biochemistry*. 4th Ed. WH Freeman. 3. Lewin B. 2004. *Genes VII*. International Ed. John Wiley & Sons. 4. Pasteur N, Pasteur G, Bonhomne F, Catalan J & Britton–Davidian J. 1988. *Practical Isozyme Genetics*. Ellis Horwood. 5. Sambrook J &Russel WD. 1989. *Molecular Cloning: A LaboratoryManual*. Vols. I-III. Cold Spring Harbor. 6. Stryer L, Berg JM &Tymocz KJL. 2004. *Biochemistry.* 5th Ed. WH Freeman. 7. https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-609364ab26da_Textbook%20Animal%20Breeding%20and%20Genetics-v17-20151122_1057.pdf 8. https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, *Genetics,* Indian Journal of Fisheries, Journal of Fish Biology The Journal of heredity

FGB 510 Microbial Genetics (2+0)

Objective	To impart knowledge of genetics applicable to microbes
Theory	
Unit-I	Basic of microbial existence: Why study the prokaryotic genetics History of Microbiology Bacterial genetics-Conjugation, sex factors; High frequency recombination; Transduction (generalized and specialized) Bacterial transformation; Mutation types, Repair mechanism, Selection of mutants Genetics of Bacteriophage-Bacteriophage classification, types, PhageT4-Structure, gene expression and genome organization Lamda phage replication, lytic and lysogeneic cycles Mechanisms of repressor synthesis and its control, auto regulation, one step growth curve; importance of bacteriophages Coalescent of bacterial population-Population reproduction models Time and effective population size, Demography Recombination and gene conversion
Unit-II	Linkage, Selection and the clonal complex- Recombination, linkage and substructure Neutrality versus Selection, Clustering Techniques; Sequence based population structure analysis
Unit-III	Population Genetics-Natural Selection, Methods for detecting presence of natural selection, Measure of genetic diversity, The concept of Effective population size, Population sub divisionPopulation Genomics- Population structure and genetic evolution-similarities and differences Bacterial Population genomics, MLVA and SNP for analysis in population genetic study, Phylogenetic resolution, Phylogeographic resolution
Unit-IV	Gene Maps Tools and protocols World Wide Web Databases Genetically modified organisms (GMOs) Technological advances Controls and cautions
Unit - V	Transposable Elements: IS elements, Tn3 family and medical significance. The Genetic and evolutionary significance of transposable elements: Use in genetic analysis and evolutionary issues.
Unit - VI	Microbial strain improvement techniques: Identification of ideal microorganisms for bioprocess, Microbial strain improvement – Genetic engineering and evolutionary engineering, Bioprocess optimization and applications in industry, agriculture and health
Suggested Readings	1. Pelczar. M.J., Chan. E.C.S., Kreig. N.R., "*Microbiology*", McGraw Hill Publishers, 5th edition, 2001.

	2. Maloy.S.R.,Cronan.J.E.,Freifelder.D., "*Microbial Genetics*", Narosa Book Distributors, 2nd edition, 2009.