

4.	Fish	Genetics	and	Breeding
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M	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	(From the subject)	rses subjects closely related to a students major		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	
С		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		5 credits
		 (The following courses, one credit each will be offered) 1. Library and Information Services 2. Technical Writing and Communication Skills 		



		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 Cour	se 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.S	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
Linit-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-TV	Cytogenetics: Cytogenetics and evolution:
	Karvotyping 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
	Application of coloction for performance improvement
	Cross breeding and Hybridization
Practical	
- i detteur	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	1. Kirpichnikov, V.S. 1981. Genetic Basis of Fish Selection. Springer-
Readings	Verlag



2. <i>Bic</i>	Lakra WS, Abidi SAH, Mukherjee SC and Ayyappan S. 2004. <i>Fisheries</i>
3. 4.	Lutz CG. 2003. <i>Practical Genetics for Aquaculture</i> . Wiley-Blackwell. Lynch M & Walsh B. 1997. <i>Genetics and Analysis of Quantitative</i>
5.	Purdom CE. 1993. <i>Genetics and Fish Breeding</i> . Chapman & Hall. Snustad DP & Simmons MJ. 1999. <i>Principles of Genetics</i> . 2nd Ed.
Jor Wil	nn ley & Sons. Stansfield WD, 1991, <i>Theony and Problems of Constiss</i> , McCraw Hill
8. Ch	Tave D. 1993. <i>Genetics for Fish Hatchery Managers</i> . 2nd Ed. apman & Hall.
9. 9 Aq	Gjedrem, Trygve et al., 2005. Selection and Breeding Programs in uaculture Springer
10 bre Ne	. KorOldenbroek en Liesbeth van der Waaij. 2014. Textbook Animal eeding and genetics. Wageningen University and Research Centre, the therlands
<u>htt</u> 601 <u>cs-</u>	tps://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40- 9364ab26da_Textbook%20Animal%20Breeding%20and%20Geneti -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
	Paul coefficient: meory, 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	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 pediaree
	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	factors and predicting random effects-BLUE and BLUP; Models for EBV Selection: Aids and methods; genetic gain and correlated response;
	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



Suggested	1. Doolittle DP. 1987. <i>Population Genetics: Basic Principles</i> . Springer-
Readings	Verlag.
	2. Falconer DS & Markay TFC. 1996. An Introduction to
	QuantitativeGenetics. 4th Ed. Addison Wesley Longman.
	3. Li CC. 1955. <i>Population Genetics</i> . University of Chicago Press.
	4. Lynch M & Walsh B. 1997. <i>Genetics and Analysis of Quantitative Traits</i> .
	Sinauer, Sunderland.
	5. Pirchner F. 1983. <i>Population Genetics in Animal Breeding</i> . Plenum
	Press.
	6. Turner HN & Young SSY. 1969. <i>Ouantitative Genetics in Sheep</i>
	Breeding. Cornell University Press.
	7. Hartl D. 1988. <i>A Primer in Population Genetics</i> . 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.imp.com/en_us/academic/impg-course-materials.html
	Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture
	Research, <i>Genetics</i> , 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 QILS- Major and minor genes, lests for detecting major
	genes
	Application of markers in selection programmes, status and their relevance;
	QTL and its application in Selection Marker Assisted Selection in Fisherical Conomic selection
Bractical	Marker Assisted Selection in Fishenes, Genomic Selection.
FIACUCAI	Estimation of genetic parameters, heritability, repeatability, and genetic
	Estimation of genetic parameters: nentability, repeatability and genetic
	Estimation of Brooding Values from various sources of information and
	their accuracies
	Construction of selection indices
	Designing and conducting challenge test for disease resistance
	Selection: hasis of selection genetic gain
	Response to selection and factors affecting response
	Aids to selection: Methods of selection
	OTL and MAS
Suggested	1. Cameron ND. 1997. Selection Indices and Prediction of Genetic Merit in
Readings	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 <i>Genetics and Analysis of Quantitative Traits</i> .
	Sinauer, underland.
	6. Pirchner F. 1983. <i>Population Genetics in Animal Breeding</i> . Plenum
	Press.



7. Turner HN & Young SSY. 1969. <i>Quantitative Genetics in Sheep</i>
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-
<u>v17-20151122_1057.pdf</u>
10. <u>https://www.jmp.com/en_us/academic/jmpg-course-materials.html</u>
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 Merphemetric analysis. Truce analysis
	Practical on synchronization of snawning. Closed lifesycle and controlled
	mating Hermone induced evulation: Collection of fich gameters. Accessing
	amete quality
	Chyopreservation
Suggested	1 Hoar WS & Randall D1 1988 Fish Physiology Academic Press
Readings	2. Kinghorn BP. 1981. <i>Quantitative Genetics in Fish Breeding</i> . University of Ediphurgh
	3 Purdom CE 1993 <i>Genetics and Fish Breeding</i> Chapman & Hall
	4. Thomas PC, Rath SC & Mohapatra KD, 2003. Breeding and Seed
	Production of Finfish and Shellfish. Dava Publ. House.
	5. Weatherely AH & Gill HS, 1988. <i>The Biology of Fish Growth</i> . Blackwell
	Synergy.
	6.Gjedrem, Trygve et al., 2005. Selection and Breeding Programs in Aquaculture Springer
	7. Rath, R.K., 2018. <i>Freshwater aquaculture</i> . Scientific Publishers.
	8. Chattopadhyay, N.R., 2016. <i>Induced fish breeding: A practical quide for</i>
	hatcheries. Academic Press.
	9. Lee, C.S. and Donaldson, E.M. eds., 2012. <i>Reproductive biotechnology</i>
	<i>in finfish aquaculture</i> . Flsevier.
	10. $https://www.wur.nl/upload_mm/d/b/b/614bcc19-036f-434e-9d40-$
	609364ab26da Textbook%20Animal%20Breeding%20and%20Genetics-
	v17-20151122 1057.pdf
	v17-20151122_1057.pdf 11. https://www.jmp.com/en_us/academic/jmpg-course-materials.html
	v17-20151122 1057.pdf 11. https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture
	v17-20151122_1057.pdf 11. https://www.jmp.com/en_us/academic/jmpg-course-materials.html Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, <i>Genetics,</i> Indian Journal of Fisheries, Journal of Fish Biology



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
	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 neritability;
	Genetics and management of wild and captive populations
	Constis management for reintroduction. In situ and an situ concernation.
	dene pool concept - primary secondary and tertiary dene pool and dene
	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
	Studios on Domostic and international guarantino process: its weaknesses
	and measures for its strengthening
	Case studies on rescue and release of animals
Suggested	Lase studies of rescue and release of animals
Boodinge	Pischwoll
Readings	2 Cloud 16 & Thorasard CH 1993 Construction of Salmonid
	Fishes NATO ASI Series Life Sciences Springer
	3 Frankham R Ballou 1D & Briscoe DA 2004 A Primer of Conservation
	Genetics Cambridge University Press.
	4. Frankham R. 1995. <i>Introduction to Conservation Genetics</i> . Annual
	Reviews of Genetics.
	5. Hartl D. 1988. <i>A Primer in Population Genetics</i> . 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. <i>Evolutionary quantitative genetics</i> . 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, <i>Genetics</i> , 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
11 1 1 1 1	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	Exposure to various open course online bioinformatics tools and
	applications
	Introduction to Riginformatics databases
	Indoduction to Diolinormatics ualabases
	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	1. Attwood TK & Smith DJP. 1999. Introduction to Bioinformatics. Addison
Readings	Wesley Longman.
	2. Brown SM. 2000. Bioinformatics: A Biologist's Guide to Biocomputing
	<i>and the Internet</i> . Eaton Publ.
	3. Lesk AM. 2008. Introduction to Bioinformatics. Oxford University Press.
	4. Mount DW. 2001. <i>Bioinformatics: Sequence and Genome Analysis</i> .
	ColdSpring Harbor Press.
	5. Rashidi HH & Buehler LK. 2005. <i>Bioinformatics Basics: Applications in</i>
	Biological Sciences and Medicine. CRC Press.
	6. Cody RP & Smith JF. 1997. <i>Applied Statistics and SAS Programming</i>
	Language. Elsevier.
	7. Littell RC, Milliken GA, Stroup WW & Wollinger RD. 1996. SAS System
	101 MIXED MODELS. SAS INSULUE. 9. Souton AM 2004, Connetic Analysis of Complex Traits Using SAS SAS
	Dubl
	9 Isik Eikret James Holland and Christian Maltecca 2017 Genetic data
	analysis for plant and animal breeding. New York: Springer
	10 https://www.wur.pl/upload_mm/d/b/b/614bcc19-036f-434o-0d40-
	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	 Lakra WS, Abidi SAH, Mukherjee SC &Ayyappan S. 2004. <i>Fisheries Biotechnology</i>. Narendra Publ. House. Pisano E. 2007. <i>Fish Cytogenetics</i>. Science Publ. Reddy PVGK, Ayyappan S, Thampy DM & Krishna G. 2005. <i>FishGenetics and Biotechnology</i>. ICAR. Caetano-Anolles G &Gresshoff PM. 1998. <i>DNA Markers:</i> <i>Protocols, Applications and Overviews</i>. Wiley-VCH. Pasteur N, Pasteur G, Bonhomme F, Catalan J & Britton-Davidian J. 1988. <i>Practical Isozyme Genetics</i>. Ellis Horwood. Sambrook J &Russel WD. 1989. <i>Molecular Cloning: A Laboratory</i> <i>Manual</i>. Vols. I-III. Cold Spring Harbor Laboratory Press Suggested Journals: Aquaculture, Aquaculture Reports, Aquaculture Research, <i>Genetics</i>, 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	1. Barnes D and Mathur PJ. 1998. <i>Methods in Cell Biology</i> . Vol. 57.
Readings	Animal Cell Culture Methods. Academic Press.
-	2. Basega R. (Ed.). 1989. <i>Cell Growth and Division: A Practical</i>
	Approach.IRL Press.
	3. Butler M and Dawson M. (Ed.). 1992. <i>Cell Culture</i> . Bios Scientific Publ.
	4. Clynes M. 1998. Animal Cell Culture Techniques. Springer.
	5. Freshnev 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. <i>General Techniques of</i>
	<i>Cell Culture</i> . Cambridge University Press.
	7. Lan F.R. 1994. <i>Culture of Animal Cells</i> . 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
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	1. Caetano-Anolles G. and Gresshoff, P.M. 1998. DNA Markers: Protocols,
Readings	Applications and Overviews. Wiley-VCH.
	2. Lehninger LA, Nelson DL & Cox MM. 2008. <i>Principles of Biochemistry</i> .
	4th Ed. WH Freeman.
	3. Lewin B. 2004. <i>Genes VII</i> . International Ed. John Wiley & Sons.
	4. Pasteur N, Pasteur G, Bonnomne F, Catalan J & Britton–Davidian J.
	1988. <i>Practical Isozyme Genetics</i> . Ellis Horwood.
	5. Sambrook J & Russel WD. 1989. <i>Molecular Cloning: A Laboratory Manual</i> .
	VOIS. 1-111. COID Spring Harbor.
	Froman
	7 https://www.wur.pl/upload.mm/d/b/b/614bcc10.026f.424o.0d40
	600364ab26da Toxtbook%20Animal%20Brooding%20and%20Constics
	v17-20151122 1057 pdf
	8 https://www.imp.com/en_us/academic/impg-course-materials.html
	Suggested Journals: Aquaculture Aquaculture Reports Aquaculture
	Research, <i>Genetics</i> , 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., " <i>Microbiology</i> ", McGraw Hill Publishers, 5th edition, 2001.



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