Genetic Engineering

Volume 1

Principles, Mechanism, and Expression

Tariq Ahmad Bhat | Jameel M. Al-Khayri
Editors

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Edited by

Tariq Ahmad Bhat, PhD
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Dedication

This book is dedicated to:

Fatima bint Muhammad Al-Fihriya Al-Qurashiya

An Arab Muslim woman who is attributed with founding the oldest existing and continually operating, and first degree-awarding educational institution for natural sciences in the world, the University of al-Qarawiyyin Fez, Morocco, in 859 CE, she is also known as “Umm al-Banīn.”

(*Source:* wikipedia.org)

About the Editors

Tariq Ahmad Bhat, PhD

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Tariq Ahmad Bhat, PhD, with 18 years of teaching experience, is a lecturer on botany in the Department of Education, Govt. of Jammu and Kashmir, India, and is engaged in active research of molecular biology, cell biology, mutation breeding, and genetic improvement of legumes and medicinal plants. He has published 10 international books, 90 research papers, review articles, and book chapters. He has participated in 50 conferences, training programs, and workshops. He is one of the founder faculty members of the Chief Minister's Super 50 NEET Programme in Jammu and Kashmir, India. He is serving as the District Coordinator Anantnag of a prestigious project on medicinal plants under financial assistance of the National Medicinal Plants Board (NMPB), New Delhi (Ministry of AYUSH), India. The Government of India conferred on him the Best innovative Science Teacher Award 2014 in recognition of his meritorious services. Dr. Bhat has received his MSc and PhD from AMU, Aligarh India.

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He has dedicated his research efforts on date palm biotechnology for the last three decades. He has published over 60 research articles and reviews in international journals in addition to 30 book chapters. Dr. Al-Khayri is editor of several special issues of international journals on date palm, biotechnology, and sustainable agriculture under abiotic and biotic stress. He is editor of 15 Springer reference books, including *Date Palm Biotechnology, Date Palm Genetic Resources and Utilization* (2 volumes), *Date Palm Biotechnology Protocols* (2 volumes), and *Advances in Plant Breeding Strategies* (9 volumes). He is a member of the editorial board and reviewers' panels of several international journals. He has participated in the organizing and scientific committees of international scientific conferences and contributed over 50 research presentations. In addition to teaching, graduate students advising, and conducting funded research projects, he has held administrative posts as Assistant Director of the Date Palm Research Center, Head of Department of Plant Biotechnology, and Vice Dean for Development and Quality Assurance. Dr. Al-Khayri is an active member of the International Society for Horticultural Science and the Society for In Vitro Biology and serves as the National Correspondent of the International Association of Plant Tissue Culture and Biotechnology. He served as a member of Majlis Ash-Shura (Saudi Arabia Legislative Council) Fifth Session. Currently, he maintains an active research program on date palm focusing on genetic transformation, secondary metabolites, and in vitro mutagenesis to enhance tolerance to abiotic and biotic stress. He is interested in the role of biotechnology in enhancing food security and the impact of global climate change on agriculture. Dr. Al-Khayri earned a BS in Biology from the University of Toledo and an MS in Agronomy and PhD in Plant Science from the University of Arkansas, USA.

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Abbreviations

A	adenine
ADA	adenosine deaminase
AFLP	amplified fragment length polymorphism
Ald	α-acetolactate decarboxylase
ALP	alkaline phosphatase
AMV	avian myeloblastosis virus
ARMS	amplification refractory mutation system
ARS	autonomously replicating sequence
BACs	bacterial artificial chromosomes
BSA	bovine serum albumin
Bst	Bacillus stearothermophilus
C	cytosine
CarE B1	carboxylesterase B1
CCCP	carbonyl cyanide m-chlorophenyl hydrazone
cDNA	complementary DNA
CE	capillary electrophoresis
CRISPR	clustered regularly interspaced short palindromic repeats
CSF	cerebrospinal fluids
CVS	chorionic villus sampling
DB 71	direct blue 71
DEAE-dextran	diethylaminoethyl-dextran
DGGE	denaturing gradient gel electrophoresis
D-LDH	d-lactate dehydrogenase
DMSO	dimethyl sulfoxide
DNA	deoxyribonucleic acid

DNase I	deoxyribonuclease I
dNTPs	deoxyribonucleoside triphosphates
DOPE	dioleylphosphatidyl ethanolamine
Dr	diacetyl reductase
dsDNA	double-stranded DNA
E. coli	Escherichia coli
EDTA	ethylene-diamine-tetraacetate
ELOSA	enzyme-linked oligonucleotide sorbent assay
EMF	electromotive force
ER	endonucleases
FBrAtio	flux balance analysis with flux ratios
FDA	Food and Drug Administration
FO	function oxidases
FRET	fluorescence resonance energy transfer
G	guanine
GE	genetically engineered
GEM	genetically engineered microorganisms
GEMs	genetically engineered microbes
GLP-1	glucagon-like peptide 1
GM	genetically modified
GMO	genetically modified organisms
GRAS	generally recognized as safe
GST	glutathione S-transferases
GTS	genomic template stability
HBV	hepatitis B virus
HFCS	high-fructose corn syrup
HFD	high-fat diet
HGT	horizontal gene transfer
HPCE	high-performance capillary electrophoresis

HPLC	high-performance liquid chromatography
HSV	herpes simplex virus
HTML-PCR	homopolymer tail-mediated ligation PCR
IEF	isoelectric focusing
IPTG	isopropyl β-d-1-thiogalactopyranoside
ITP	isotachophoresis
LAB	lactic acid bacteria
Ldh	lactate dehydrogenase
LIF	laser-induced fluorescence
lncRNA	long non-coding RNA
LTRs	long terminal repeats
MAB	marker-assisted breeding
MAC	mammalian artificial chromosome
MCE	microchip electrophoresis
MCF	microbial cell factories
MCS	multiple cloning site
MFO	mixed function oxidases
mpd	methyl parathion hydrolase gene
MT	metallothionein
OP	organophosphorus
ORF	open reading frames
Ori	origin of replication
PACs	P1-derived artificial chromosomes
PAGE	polyacrylamide gel electrophoresis
PARα	proliferator-activated receptors α
PCR	polymerase chain reaction
PFE	pulsed-field gel electrophoresis
pHSA	plasma HSA
Pnk	polynucleotide kinase

PNP	p-nitrophenol
PPARα	proliferator-activated receptors α
PTM	post-translational modifications
PVDF	polyvinylidene fluoride
pytH	pyrethroid hydrolase gene
QS	quorum sensing
rDNA	recombinant DNA
RFLP	restriction fragment length polymorphism
rHSA	recombinant HSA
RM	restriction/modification
RNA	ribonucleic acid
RT	real-time
RT-PCR	reverse transcriptase PCR
SDS	sodium dodecyl sulfate
SDS-PAGE	sodium dodecyl sulfate-polyacrylamide gel electrophoresis
SNP	single nucleotide polymorphism
sRNA	small regulatory RNAs
SSC	saline-sodium citrate
ST	S-transferases
T	thymine
TAE	tris/acetate/EDTA
YAC	yeast artificial chromosome

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Foreword

Genetic engineering is the science of manipulating the genetic material of an organism. The first artificial genetic modification accomplished by Herbert Boyer and Stanley Cohen in 1973 was the result of a series of advancements in techniques that allowed the direct modification of the genome by transferring genetic information from one organism to the other. Important advances included the discovery of restriction enzymes by Werner Arber and Hamilton O. Smith in the 1970s and DNA ligases by combined efforts of Gellert, Lehman, Richardson, and Jerard Hurwitz in the 1960s and early 1970s, the ability to design plasmids, and technologies like polymerase chain reaction (PCR) by Kary Mullis in 1983, and DNA sequencing by Frederick Sanger, Walter Gilbert, Allan Maxam in 1977 and John Craig Venter in 1999.

Several other discoveries and developments that occurred later brought this technology of genetic engineering to the level that we see today. From 1990 to 2003, the Human Genome Project succeeded in mapping the human genome with more than 20,000 genes identified and their genomic loci documented. Dolly was cloned under the leadership of Ian Wilmut in 1996. Transformation of the DNA into a host organism was accomplished with the invention of biolistics, agrobacterium-mediated recombination, and microinjection. The first genetically modified (GM) animal was a mouse created in 1974 by Rudolf Jaenisch. In 1976 the technology was commercialized, with the advent of genetically modified bacteria that produced somatostatin, followed by insulin in 1978. In 1983 an antibiotic-resistant gene was inserted into tobacco, leading to the first genetically engineered (GE) plant.

Advances followed that allowed scientists to manipulate and add genes to a variety of different organisms and induce a range of different effects. Plants were first commercialized with virus-resistant tobacco released in China in 1992. The first genetically modified food was the Flavr Savr tomato, marketed in 1994. By 2010, 29 countries had planted commercialized biotech crops. In 2000 a paper published in Science introduced golden rice, the first food developed with increased nutrient value.

In the present decade of 2010–2020, the development therapies that have been theorized and studied for years are finally being approved for humans, as the discovery of CRISPR, possibly the greatest achievement in the history of genetics, takes hold in the world.

Volume 1 of this book, *Genetic Engineering*, encompasses all the basic concepts of the various components of recombinant DNA (rDNA) technology. The book has been designed to communicate the fundamental principles of genetic engineering through an explanation of various molecular biology phenomena and the development of various technologies over the years. The various chapters have been written by young and experienced experts in their respective fields from different elite educational institutions across the globe. I applaud the editor, Dr. Tariq Ahmad Bhat, as well as the book chapter contributors for successfully bringing together this volume.

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Preface

The advent of biotechnology has forever changed human perception of living entities. Genetic engineering enables the precise control of the genetic composition and gene expression of organisms directed toward the advantage of human well-being. Innovative applications have emerged in environmental sustainability, food and nutritional security, and medicinal advancement. The utilization of this powerful technology solicits contrasting opinions among scientists, politicians, and the public in relation to biosafety and bioethics. This necessitated the engagement in research aimed at understanding the safety of genetic engineering products and prompted the development of national and international policies. This book addresses these aspects in two volumes: *Volume 1*, *Genetic Engineering: Principles, Mechanism, and Expression*, and *Volume 2*, *Genetic Engineering: Applications, Bioethics, and Biosafety.*

Volume 1 consists of 12 chapters covering genetic engineering concepts, molecular tools, and technologies utilized in the manipulation, amplification, and introgression of DNA. Topics covered are concepts of genetic engineering, enzymes of genetic engineering, tools used in genetic engineering, the introduction of recombinant DNA (rDNA) into host cells, linking of the desired gene with DNA vector/gene cloning vector, polymerase chain reaction (PCR), concept and nature of genes, blotting techniques, chromosome jumping, electrophoresis, genetically engineered (GE) microorganisms, and molecular markers and their applications.

This book is a valuable asset to upper-undergraduate and postgraduate students, teachers, and researchers interested in cell biology, genetics, molecular genetics, biochemistry, biotechnology, botany, zoology, and agriculture sciences. The chapters are contributed by experts in their fields, presenting recent contemporary developments in genetic engineering research supported with illustrations, tables, and recent references. We are thankful to all the authors across the globe who contributed their research output in the form of book chapters to make our project a successful endeavor. We wish to present our gratitude to the contributing authors for their generous cooperation and to Apple Academic Press (AAP)/CRC

Press/Taylor and Francis Group for giving us the opportunity to publish this work.

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CHAPTER 1

Concepts of Genetic Engineering

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ABSTRACT

Genetic engineering, also known as gene modification or gene editing, is a field of biotechnology that involves the direct manipulation of an organism's genetic material in order to modify or add traits. This can be done through a variety of techniques, such as the insertion of genetically modified DNA into an organism, or the disruption or suppression of certain genes. Genetic engineering has the potential to revolutionize the way we produce food, create new medicines, and address environmental challenges. However, it is also a controversial field, with many ethical, social, and environmental considerations.

One of the key concepts in genetic engineering is the use of genetically modified organisms (GMOs). These are organisms whose genetic material has been modified using genetic engineering techniques. The goal of using GMOs is often to introduce new traits or characteristics into the organism, such as increased resistance to pests or diseases, or enhanced nutritional value. However, there are concerns about the safety of GMOs, both for the environment and for human consumption.

Another important concept in genetic engineering is gene editing, which involves the precise modification of an organism's genetic material at the DNA level. Gene editing has the potential to be used for a wide

Genetic Engineering, Volume 1: Principles, Mechanism, and Expression. Tariq Ahmad Bhat & Jameel M. Al-Khayri (Eds.)

range of applications, including the treatment of genetic diseases and the production of new medicines. However, there are also concerns about the potential ethical implications of gene editing, such as the creation of designer babies or the enhancement of human traits.

Overall, genetic engineering is a complex and rapidly-evolving field with the potential to significantly impact many aspects of our lives. While it offers many benefits, it also raises important ethical, social, and environmental considerations that need to be carefully considered as the field continues to develop.

1.1 HISTORICAL PERCEPTIVE OF GENETIC ENGINEERING

The structural elucidation of genetic material and code marked a new dawn in the field of science. It became very evident that genetic material conceals numerous biological secrets inside, which were yet to be explored. Post-1970s led to huge technological advancement, which paved the way towards new analysis and manipulation in genetic material. Consequently, many breakthroughs were achieved after the detailed structure of DNA and RNA was documented. It was only after World War II, people mainly biologists and philosophers began to analyze a growing link between biology and technology. Eventually, a new field of science which could be used for the improvisation of human life evolved as genetic engineering. The idea of changing the human nature may thus benefit the society. It was only after Second World War, scientists began to institutionalize biology and technology by establishing new departments, institutes, and ministries. Thus, with the new advances in the field of molecular biology, genetic engineering became more of science than merely an art.

The concept of genetic engineering dates long before the structural documentation of DNA and RNA. However, the expression "genetic engineering" was first used by the science-fiction novelist but not by scientist. It was in 1951; Jack Williamson used the term "genetic engineering" in his novel "Dragon's Island" (Williamson, 2012).

People around the globe were already familiar with the art of using living micro-organisms to manufacture new products. The best example in this regard is the process of fermentation, where ancient people utilized the service of living micro-organisms to get new and improved products such as bread and alcohol. As the events progressed, knowledge of protein synthesis from regions of deoxyribonucleic acid (DNA) (called genes) provided a key to in-depth exploration in the DNA structural base.

With plenty of exploration and subsequent advancement of new genetic techniques, expression of gene was made conceivable regardless of its origin, in a simple micro-organism like *Escherichia coli* (*E. coli*) leading to the increased production of the product coded by that gene. Based on the same principle, vast number of other organisms both micro and macro were used to get efficient and large quantity of products. It was only before 1990 a new technique namely protein engineering became possible as a new outcome of genetic engineering (Maloy & Hughes, 2013). With the course of time, new discoveries and advancements came into existence which changed the whole scenario of the scientific world. It was Karl Ereky who specified a whole new subject as biotechnology (Fári & Kralovánszky, 2006). It is very important to mention that the term genetic engineering was coined in 1940 by A Jost. However, the most important discovery in the arena was that of enzymes and vectors. These two together changed the whole concept of biology and hence marked the beginning of a new dawn in the scientific world.

1.2 KEY CONCEPTS IN GENETIC ENGINEERING

1.2.1 GENE

Gene is the basic physical, structural, and functional unit of inheritance which occupies a fixed place on a chromosome. It may be chemically defined as a sequence of nucleotides carrying specific hereditary information (Pearson, 2006). More specifically, it is the nucleic acid DNA or RNA which codes the synthesis of the gene product, whether it is RNA or protein (Morange, 2000).

1.2.2 RECOMBINANT DNA (RDNA)

Recombinant DNA (rDNA) can be defined as a solitary chimeric DNA produced by joining two or more dissimilar fragments of DNA from different organisms. The technique used to produce rDNA is called rDNA technology. The organism is categorized as donor and host. The donor is the organism from which the isolation of DNA is done and the host is the organism in which this DNA is incorporated. Paul Berg, Herbert W Boyer, and Stanley N Cohen are the pioneers of rDNA technology. The first ever rDNA molecule was created by recombining the SV40 monkey DNA virus genome and a bacterial virus known as phage λ (Robl, Wang, Kasinathan, & Kuroiwa, 2007).

1.2.3 VECTORS-DELIVERY SYSTEM IN RECOMBINANT DNA (RDNA) TECHNOLOGY

Vectors are important tool in rDNA technology as they act as transporters and thereby work as vehicles which deliver the genetic material in the organism of interest. Vectors may thus be defined autonomously replicating DNA molecule engaged to transport foreign hereditary material to host cells. Vectors are basically transgenic DNA bodies which possess a larger unit as foundation and smaller unit as foreign DNA. The smaller foreign DNA is ultimately expressed in the host cell thereby is transmitted. Vectors are broadly classified into two types, i.e., cloning vector and expression vector. Cloning vector is used to amplify the number of copies of a cloned DNA fragment. However, Expression vector is designed to for expressing foreign gene into a protein.

1.3 PROPERTIES OF AN EFFICIENT AND IDEAL VECTOR

An efficient vector should possess the following properties:

- The first and foremost property which an ideal vector should possess is an autonomous replicating nature which means it should possess Ori (origin of replication) region.
- It should possess at least a selectable marker, e.g., antibiotic resistance marker.
- Should possess a screenable marker/scorable marker. Scorable marker produces an end product which can easily be noticed by means of a simple and quantitative assay. The examples include markers of β-galactosidase, green fluorescent protein, etc.
- Occurrence of unique restriction enzyme site. This is very important as it forms the main criterion for any vector to be used in rDNA technology.

- Should possess several cloning sites.
- Should possibly be small in size and easy to handle.
- Should kick off DNA replication autonomously to get numerous copies.
- Presence of suitable regulatory elements for expressing foreign gene.
- The selection of a suitable vector depends mainly on the size limit of inserted DNA and category of host projected for cloning.

The other classification of vectors is based on its transmitting form and includes synthetic or artificial chromosomes, plasmids, viruses, and cosmids. However, of all four types, the most commonly used vectors include viruses and plasmids. Vectors have the property of being transcribed, translated, inserted, and then expressed.

1.4 PLASMIDS

These vectors include double-stranded spherical DNA having the property of self-replication in the host. They are primarily characteristic of prokaryotes but can also exist in eukaryotes. Because of autonomous self-replicating behavior, they are also known as replicons. Plasmids mainly carry genes for antibiotic resistance which later on acts as marker in rDNA technology. Plasmids are of two types, i.e., integrating plasmids and non-integrating plasmids. As the name specifies, non-integrating plasmids don't unite with the host DNA and replicate autonomously when the host cell divides. However, integrating plasmids amalgamate with the host DNA to get replicated. The size of plasmid ranges from few kbs to 100 kbs. Examples of plasmid vectors include pBR322 and pUC vector (Figure 1.1).

1.5 VIRUSES

Viruses play a key role as carriers and execute this role by *in vivo* and *in vitro* methods. Viruses transfer genes by the process of transduction. Viral vectors are primarily pathogenic but their pathogenicity is minimized by remodeling their genetic structure and by scissoring the gene of replication. These viruses can only infect and can't reproduce rendering them

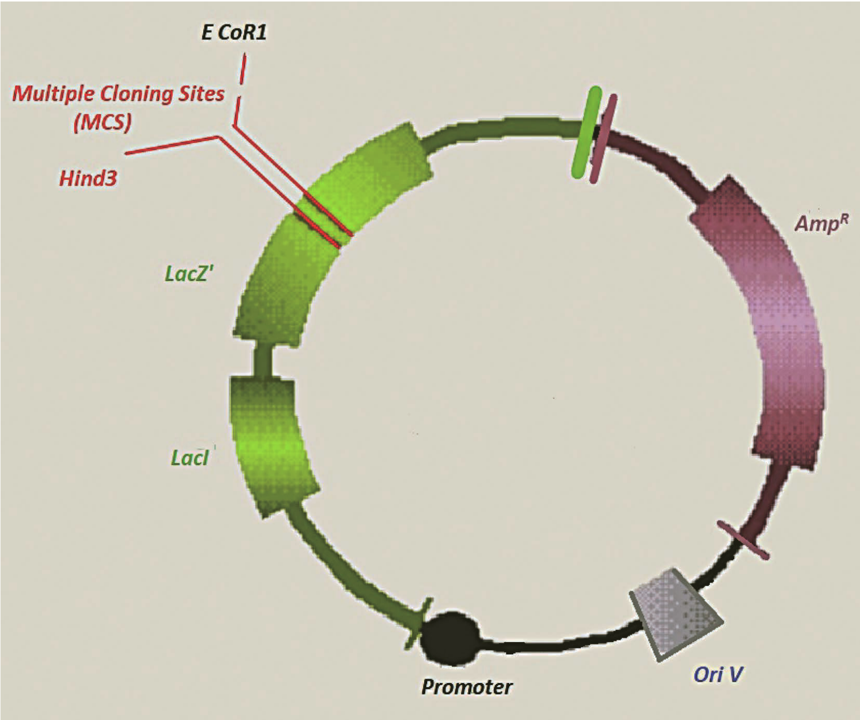

FIGURE 1.1 Diagram showing a plasmid vector construct from the pUC family consisting of ampicillin-resistant gene, promoter, LacI repressor gene, origin of replication LacZ gene for peptide of galactosidase. It also contains multiple cloning regions showing different restriction endonucleases.

harmless. Viruses are very stable and concrete. Viral vectors can infect multiple types of cells thereby are diverse in nature compared to plasmid. Avery, a smaller number of naturally occurring viruses manufacture single-stranded DNA in their life cycle. Examples include M13, fl, and fd and have been manipulated to be suitable vector (Figure 1.2).

1.6 COSMID

The huge drawback of the plasmid vector is its transformation inefficiency of cloning large segments of DNA. In order to overcome this problem, a new type of vector has been designed with high effectiveness compared to the plasmid vector. The cosmid vector is the blend of the plasmid

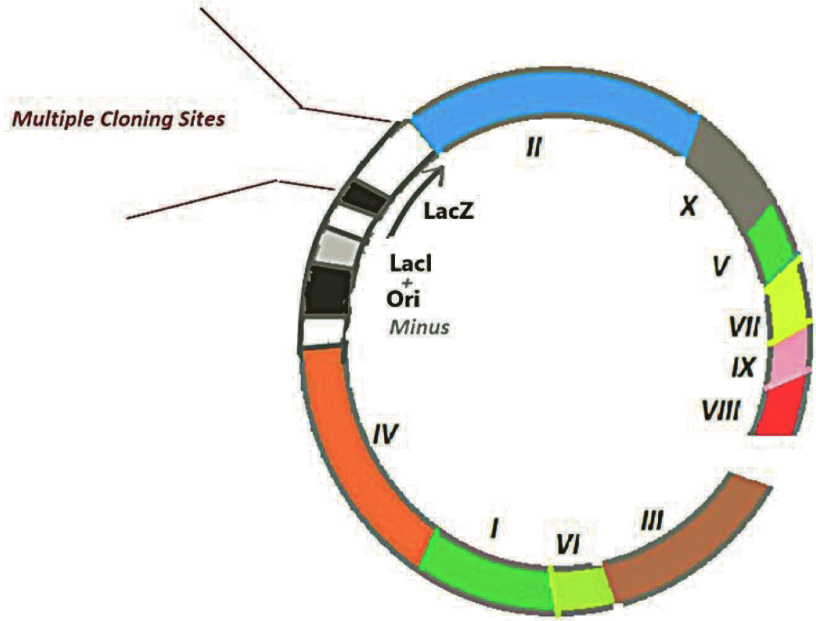

FIGURE 1.2 Diagram showing M13mp18 viral vector showing multiple cloning sites.

vector and the lambda phage *cos* sequence (Hohn & Murray, 1977). These arrangements enable target DNA to be incorporated into the λ head (Chauthaiwale, Therwath, & Deshpande, 1992). They were first described by Collins and Hohn in 1978.

The cosmid vector can hold up to 45 kb of DNA while plasmid and λ phage vectors are limited to 25 kb (Hohn & Murray, 1977).

The main difference compared to usual plasmid vectors is the presence of a small piece of lambda DNA, known as the cohesive end site. Lambda DNA in the virus is linear with two complementary single-stranded ends, therefore, are called the cohesive ends or *cos* sites (Figure 1.3).

1.7 SYNTHETIC OR ARTIFICIAL CHROMOSOMES

These are also cloning vectors that transport larger DNA inserts than plasmids or lambda-phage-derived vectors. Artificial chromosomes contain all

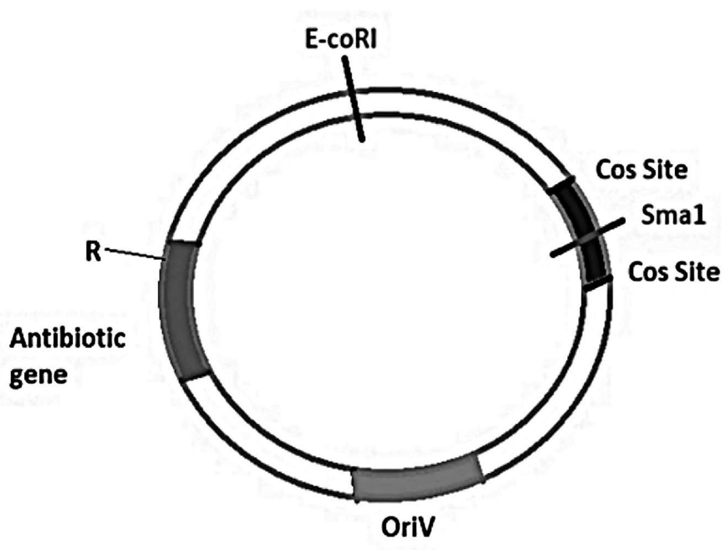

FIGURE 1.3 Diagram showing structure of cosmid vector–plasmid vector + Cos site.

the elements that are critical for replication and stability of the molecule within the host cell (O'Brien & Lummis, 2011). For instance, the first artificial chromosome, known as yeast artificial chromosome (YAC) vectors, is able to bear DNA inserts as huge as 2,000 kb. Similarly, bacterial artificial chromosomes (BACs) and P1-derived Artificial chromosomes (PACs) were designed to address the difficulty of insert chimerism and instability (Robl et al., 2003). Other examples include mammalian artificial chromosomes (MACs) designed for mammalian cells, including human cells (Figure 1.4 and Table 1.1).

1.8 BASIC STEPS REQUIRED IN GENETIC ENGINEERING

1.8.1 ISOLATION OF DNA

Genetic material is contained inside the cells. It has to be obtained in pure form without even the attached histones and other proteins. The first step in DNA purification is to open the cells and release DNA. The method should be gentle to preserve the native DNA; the approaches to break the cells vary due to the variability in the cell structure.

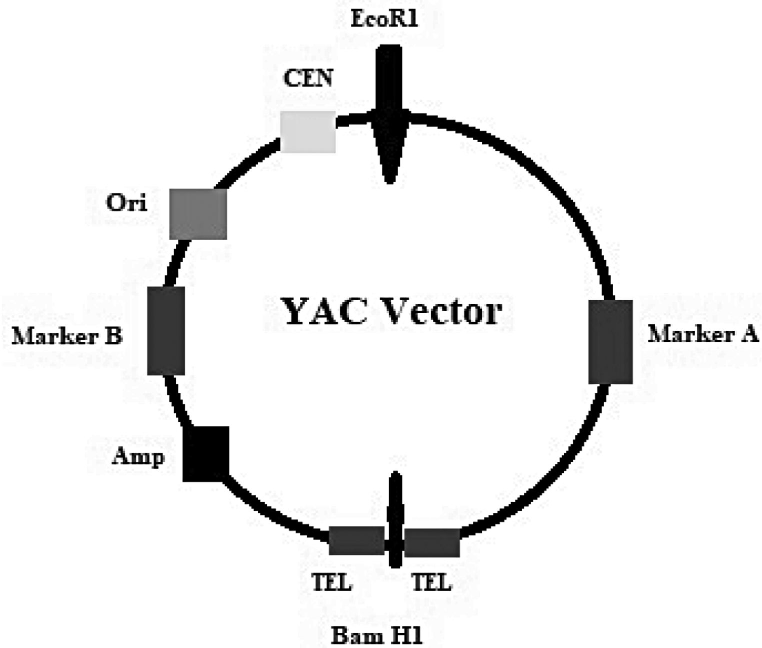

FIGURE 1.4 Diagram showing YAC vector.

TABLE 1.1 Some Milestones in the History of Genetic Engineering

Sl. No.	Year	Event
1.	1917	The term Biotechnology coined by Karl Ereky.
2.	1940	The term Genetic Engineering coined by A. Jost.
3.	1943	Penicillin produced on an industrial scale.
4.	1944	Avery, Macleod, and Mc Carty demonstrated that DNA is the genetic material.
5.	1953	The structure of DNA was determined Watson and Crick.
6.	1958	For studying the primary structure of proteins and genetic recombination in a bacterium F. Sanger, Joshua Lederberg, G.W. Beadle, and Edward L. Tatum were jointly awarded the Noble prize in chemistry and physiology or Medicine.
7.	1959	Arthur Kornberg and Severo Ochoa were awarded the Noble prize for the synthesis of DNA and RNA.
8.	1961–1966	The entire genetic code is deciphered.
9.	1970	The First Restriction endonuclease, Hind II was isolated by Hamilton O. Smith, Thomas Kelly, and Kent Wilcox from the bacterium *Haemophilus influenza.*

TABLE 1.1 *(Continued)*

Sl. No.	Year	Event
10.	1973	Boyer and Cohen established recombinant DNA technology.
11.	1974	Rudolf Jaenisch created a genetically modified mouse.
12.	1977	Fredrich sanger developed a method for sequencing DNA.
13.	1978	Genentech produced human insulin in *E. coli*
14.	1983	PCR developed by Karry Mullis.
15.	1983	An antibiotic-resistant gene was introduced into tobacco, leading to the first genetically modified plant.
16.	1987	Recombinant vaccine for hepatitis B (HBsAg) became the first synthetic vaccine for public use.
17.	1988	PCR method was published.
18.	1990	The human genome was officially initiated.
19.	1994	The first GM food known as FlavrSavr tomato has been commercialized globally.
		The FDA reports that genetically modified tomatoes are as safe as traditional tomatoes.
20.	1995	The first genome sequence for the bacterium *Haemophilus influenza* has been completed.
21.	1996	The commercial planting of genetically modified crops has been launched.
22.	1997	India became the fourth country in the world to develop an indigenous hepatitis B vaccine.
23.	1997	The first-ever mammal clone named Dolly was developed by Wilmut and Campbel. Dolly was a sheep with a mother and no father.
24.	2000	GM rice, called golden rice, rich in beta carotene, the precursor of Vitamin A, has been developed.
25.	2001	Human genome is sequenced.

1.8.1.1 LYSIS OF CELLS

The lysis or breakdown of bacterial cells is brought about by the use of an enzyme Lysozyme and the chemical ethylene-diamine-tetraacetate (EDTA) followed by the addition of detergents, namely sodium dodecyl sulfate (SDS).

The lysis of animal cells is directly carried out by treating them with a detergent-like SDS. Plant cells require very harsh treatment to break them open. Besides the treatment of enzymes like *cellulase* and *pectinase*, the cells are frozen and subsequently crushed in mortar and pestle.

1.8.1.2 PURIFICATION OF DNA

This involves the complete breakdown or removal of all the cellular materials other than DNA. This is achieved by homogenizing and centrifuging the treated cells to break the cells and their nuclear envelopes. The homogenized product is then treated with proteases to digest histones and other proteins; ribonucleases to digest RNA; amylases and lipases to digest polysaccharides and lipids, respectively. DNA remains intact. This DNA is precipitated by adding ethanol. DNA appears as a mass of very fine threads that can be separated by spooling or winding over a fine appliance.

1.8.2 GENERATION OF DNA FRAGMENTS

The desired genes (gene of interest) to be cloned are prepared in three ways:

1. In the first method, the gene of interest is isolated from the total genomic DNA of an organism. To isolate a gene, the genomic DNA is treated with a restriction endonuclease enzyme to cut it into many chunks. These pieces/fragments of DNA are then separated according to their length by electrophoresis. The separated DNA segments are finally used for cloning.
2. In the second method, the desired gene is synthesized using reverse transcription of the mRNA of the gene. The new DNA formed by this process is known as complementary DNA (cDNA).
3. In the third method, the preferred gene is produced by a programmed machine referred to as a DNA synthesizer or gene machine. The gene is thereby amplified by PCR and desired DNA (gene of interest) is referred to as transient or target DNA or donor DNA.

1.9 ISOLATION OF DNA VECTOR

The DNA, which is used for transferring the desired DNA (gene of interest) into a host cell or organism, is known as a vector. It is also called a cloning vehicle or carrier molecule. They are self-replicating in an appropriate host cell. Vectors are of two kinds: plasmids (e.g., pBR322) and DNA viruses (e.g., lambda phages).

1.10 CONSTRUCTION OF RECOMBINANT DNA (RDNA)

Both the passenger and vector DNAs are separated with the same restriction endonucleases (ER) to produce complementary sticky ends. Self-ligation is prevented by using *alkaline phosphatase* (ALP). Both passenger and vector DNAs are now joined together using DNA ligase (Gupta, Sengupta, Prakash, and Tripathy, 2017). The vector is guaranteed to receive only one passenger DNA. Inserting the selected DNA (passenger DNA) into the cloning vector (e.g., plasmid) produces rDNA. The rDNA is also called Chimeric DNA. Chimera in Greek Mythology refers to a monster that has a lion's head, a goat's body, and a serpent's tail.

1.11 INTRODUCTION OF RDNA INTO HOST CELL

Introducing rDNA into a host cell is a significant step in genetic engineering. It is the efficiency of this process that determines success. This is accomplished by any of the methods discussed in subsections.

1.11.1 TRANSFORMATION

Direct transformation of DNA fragments in the medium by bacterial cells is called transformation. This method was first adopted in 1970 by Mandell and Higa (1970). The ability of bacterial cells to take DNA from the medium is known as competence.

In transformation, the alien DNA is injected into a bacterial cell (for example, E-COLI). The uptake of Foreign DNA by E-coli is carried out in ice-cold $CaCl_2$ (0–5°C) trailed by heat shock (37–45°C) for about 90 seconds.

1.11.2 TRANSFECTION

The direct intake of naked DNA from the culture medium by eukaryotic cells is termed as transfection (Neumann, Schaefer-Ridder, Wang, & Hofschneider, 1982). Transfection is similar to transformation in the case of bacteria. It occurs in plant cells and animal cells.

In this method, DNA is first dissolved in the phosphate buffer and Calcium chloride solution is added to it which leads to the formation of calcium phosphate precipitate. The precipitate is then added to the cells which lead to the adherence of the precipitate particles with the cell surface. The cells engulf the particles along with DNA by the process of phagocytosis. The DNA entering the cell is integrated with the cell's genome.

1.11.3 CONJUGATION

A naturally occurring microbial recombination also referred to as bacterial mating which occurs when two bacteria (one donor and one recipient) meet together, join by a cytoplasmic bridge or conjugation tube, and exchange the DNA (from donor to recipient). Within the recipient cell, the new DNA either integrates with the chromosome or remains free.

1.11.4 ELECTROPORATION

Electroporation works on the principle of high voltage electrical impulses. Electroporation is a technique that uses membrane permeability through the electric field. Neumann et al. reported in 1982, how alien DNA can be introduced into mouse cells using short pulses of high voltage electric field (Neumann et al., 1982). It causes the absorption of DNAs into protoplasts through the temporary permeability of the plasma membrane to macro-molecules. Electric shocks generate pores in the membrane by damaging them. DNA diffuses through these membranes immediately after the electric field is applied. Transformation of *E. coli* cells by electroporation was finally published in 1988 (Carter & Shieh, 2015).

1.11.5 GENE TRANSFER THROUGH LIPOSOMES

Liposomes are circular lipids with an aqueous interior that can transport nucleic acids. The liposome-mediated gene transfer is referred to as Lipo-fection (Carter & Shieh, 2015). This technique was used as a carrier for the incorporation of nucleic acids into plant protoplasts. The liposome-treated pieces of DNA are encapsulated in them. These liposomes may then adhere to cell membranes and merge with them to transfer DNA fragments. In this way, DNA penetrates the cell and then into the nucleus.

1.11.6 DIRECT TRANSFER OF DNA

1.11.6.1 PARTICLE BOMBARDMENT OR BIOLISTICS

Shooting of plant or animal cells by DNA-coated gold or tungsten particles for introducing DNAs into cells. It is also known as microprojectile bombardment. This method is employed for incorporating rDNA into plant cells, fungal cells, animal cells, and cell organelles such as mitochondria and chloroplast (O'Brien & Lummis, 2011). The instrument used to shoot the DNA into the cells is called a Gene gun or Microprojectile gun. Vector is not used in this method to incorporate rDNA into the host cells. The gene gun is used in place of Vector.

1.11.6.2 MICRO-INJECTION

It refers to the injection of DNAs or cell organelles directly into host cells using an injection method. This DNA is usually employed to inject the DNA directly into the animal cells, eggs, zygotes, and plant protoplasts. In this method, fertilized egg (Host cell) is transferred into a microscopic slide placed under the microscope. The host cell is then maintained in place using a suction pipette. One end of the sucking pipette is positioned on the surface of the cell and gentle suction is applied on its other end. The rDNA is sucked into a glass injection needle and is gently inserted into the zygote by viewing through the microscope. The rDNA is delivered into the zygote and the needle is drawn back carefully. In this way, the rDNA gets into the genome of the zygote.

1.12 SELECTION AND MULTIPLICATION OF RECOMBINANT HOST CELLS

Selection is a fundamental process in which, when the rDNA is inserted into a particular host cell, it becomes necessary to detect the cells that have received the recombinant or foreign DNA molecule. This process is referred to as Screening or Selection. A Host cell containing rDNA is called recombinant or transformant. In this step, the transformed cells are separated from the non-transformed cells by using various methods such as antibiotic resistance, colony hybridization, and blotting tests, etc., using marker genes. The recombinant cells are mass cultured to test the purity of the products of the cloned genes.

1.13 EXPRESSION OF THE CLONED GENES

Finally, consideration should be given to ensure that the gene of interest is expressed as a functional protein. It is isolated and immunologically tested. The recombinant producing pure product (e.g., insulin) can readily be used in the future. The transformed host cells are also multiplied to produce enough copies (Figure 1.5).

1.14 APPLICATIONS OF GENETIC ENGINEERING

Manipulation of genetic constitution of organisms by inserting a gene of interest is called Genetic engineering. In genetic engineering, a novel gene can be incorporated into closely linked organisms as well as unrelated organisms. Through genetic engineering, many novel strains of micro-organisms, plants, and animals have been developed. These are very useful in agriculture, industries, pharmaceuticals, and environment.

1.14.1 TRANSGENIC ANIMALS

Transgenic animals are developed by manipulating their genetic makeup and introducing a new gene which is later expressed. These animals are utilized in the following ways:

- Transgenic animals are purposely designed to understand the control of genes and their impact on the normal functioning of the body and its developments. The best example in this regard is studying the biological role of insulin-like growth factor.
- The transgenic animals are developed to boost our understanding of result of genes which have role in development of diseases. Eventually, transgenic animals serve as model for human diseases.
- Transgenic animals are developed by introduction of a portion of DNA that encodes a product from the organism. Some of the

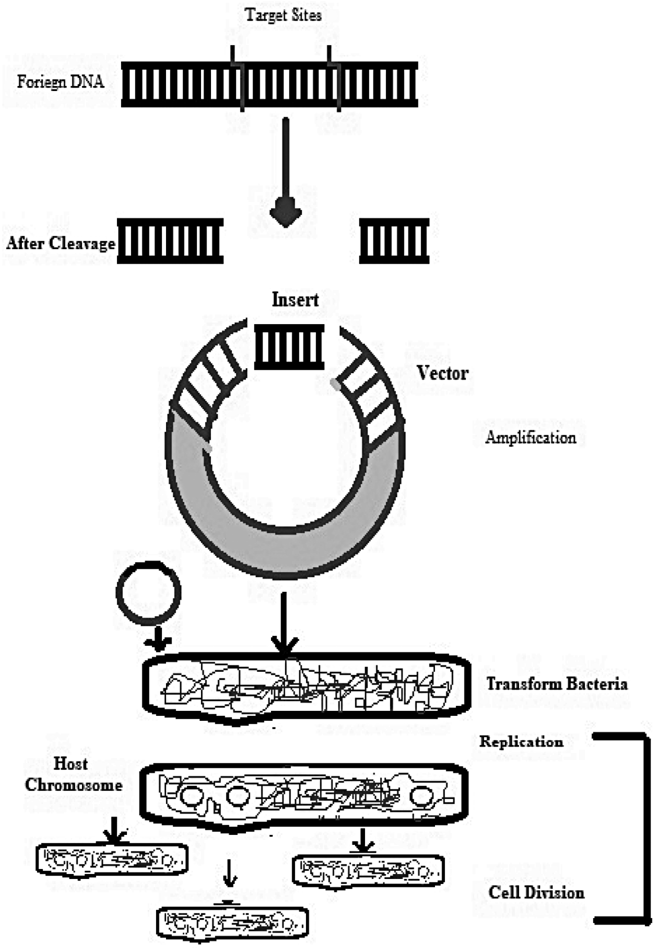

FIGURE 1.5 The process of genetic engineering.

useful biological compounds produced by this include a human protein namely alpha-1 antitrypsin used to treat emphysema. The first transgenic cow, Rosie, formed the human protein-rich milk; besides it possessed human alpha-lactalbumin, a nutritionally balanced product for babies. Transgenic cows with K-casein gene-insert produce milk rich in K-casein. This milk is likely for cheese making. Transgenic mice are also produced to test the efficacy and safety of vaccines like COVID-19 and HIV.

- Transgenic animals with high sensitivity to toxins are produced to observe and analyze the toxicity of drugs.
- Transgenic goats with tPA gene produce plasminogen activator in the milk. The tPA is used to dissolve blood clots.

1.14.2 TRANSGENIC PLANTS

The exercise of genetically modified (GM) plants has revolutionized the whole world and are very handy in the following ways:

- Genetic modification resulted in productions of better crops which are very resistant to abiotic stresses like frost, high temperature, drought, and high osmolarity, etc. (Davies, 2007).
- The use of synthetic pesticides has been declined as the crops are originally being GM for pest resistance.
- Damage to the crop after harvesting is also reduced.
- The nutrient content of soil is also preserved due to efficient mineral uptake by these crops.
- Food produced from GM crops has better dietary and nutritional value.
- Genetic alteration has been employed to generate need specific plants to deliver resources to industries like starch, fuel, pharmaceuticals, etc.

1.14.3 PRODUCTION OF PEST RESISTANT PLANTS

1.14.3.1 BT COTTON

The soil bacterium *Bacillus thuringiensis* transcribes crystal proteins known as *cry proteins*. These proteins are lethal to larvae of insects like Tobacco budworm, beetle worms and mosquitoes. The cry proteins are present in inactive form as protoxins and get transformed into active form when internalized by the organism, as the alkaline pH of gut solubilizes the toxin. The active toxin gets attached to the exterior of epithelial cells of midgut and generates pores. This results in enlargement and lysis of cells which ultimately causes the death of the Larva. These genes (cry genes) are isolated from the bacterium and integrated into numerous plants like tomato, cotton, corn, rice, soybean, etc. (Newell, 2000).

Below are the names of some of the cry genes encoding proteins against pests:

- Cry I Ac and cry II Ab manages cotton bollworms;
- Cry I Ab manages corn borer;
- Cry III Ab manages Colorado potato beetles.
- Cry III Bb manages corn rootworm.

1.14.3.2 DEFENSE AGAINST NEMATODES

Yield of tobacco plant is greatly affected by nematode namely *Meloidogyne incognita*. In order to prevent this. A special gene from the parasite is incorporated into the plant by means of *Agrobacterium* vector. The genes are incorporated in such a way that both sense and antisense RNA get formed. Being complementary to each other, they form double-stranded ribonucleic acid (RNA). As a result of this, specific RNA of nematode gets neutralized. This process is called RNA-interference. The whole process result nullifies the host and cannot assemble with a transgenic host which contributes in the host plant defense.

1.14.3.3 USE OF RDNA TECHNOLOGY IN THE MEDICAL FIELD

rDNA technology has paved the way in the production of highly efficient therapeutic drugs. Furthermore, therapeutics produced by recombination does not produce any harmful and unnecessary immunological response, which is very common in analogous products isolated from non-human resources. The current tally of approved recombinant therapeutics is 30. Out of these 30, 12 are already marketed in India.

1.14.3.4 HIMULIN – GENETICALLY ENGINEERED (GE) INSULIN

Himulin is genetically engineered (GE) form of insulin. Structurally human insulin contains two polypeptide chains as chain A and chain B, bonded by disulfide bridges.

Insulin is produced in an inactive form as prohormone and has to be processed before it attains complete functional structure. During its maturation, a polypeptide, namely C-peptide is scissored and maturation is attained. American company namely Eli-Lilly in 1983 synthesized two

DNA sequences responsible for producing chain A and B of functional insulin. They introduced this DNA in *E. coli* plasmid thereby producing insulin. Polypeptide chains produced were harvested and linked by the introduction of disulfide bonds.

1.14.3.5 GENE THERAPY

With the advancement of genetic engineering, it is now possible to treat certain genetic diseases. The method relays on the introduction of genes in cells and tissues of that individual. The defective gene is primed and new normal gene is delivered into the embryo or individual. Eventually the normal gene replaces the faulty mutant allele. The new genes are introduced in individual, and the process is mediated by special transporters called vectors. Viruses which infect the host and introduce their own genetic material there are designed in such a way that they act as vectors. The first documented gene therapy was done in the 1990s to a four-year-old girl, who had a deficiency of adenosine deaminase (ADA). Since ADA deficit can be corrected by bone marrow transplantation in certain children but it is not fully remedial. Lymphocytes are developed in a functional ADA. cDNA is incorporated into lymphocytes. These lymphocytes are then transferred in patient's body. A permanent cure is only possible if the same gene is incorporated in the patient's bone marrow cells in the embryonic stage.

1.14.3.6 MOLECULAR DIAGNOSIS

rDNA techniques like PCR (polymerase chain reaction) are useful in the early diagnosis of disorders. The cloned genes are also employed as 'probes' to spot the existence of complementary DNA strand. Eventually, a probe is a single-stranded DNA that is labeled with a radioactive tag and is used to discover its complementary DNA by hybridization. Afterwards, recognition of radioactivity by autoradiography is done. Existence of a normal or mutant gene can be identified by this method. Thus, PCR is a very powerful tool in the detection of genetic disorders besides other diseases like HIV. During the current global crises of COVID-19, PCR has served one the best and only technique to identify the presence of the virus.

1.15 SAFETY CONCERNS REGARDING GENETIC ENGINEERING

Genetically modified organisms (GMO) are primarily developed by introducing a minute segment of DNA from a "donor" into a "recipient" organism. The genome of the new organism is thus most likely that of the recipient organism. Consequently, the new organism contains fraction of recipient thus accessing the properties of recipient may provide as initial insight and assessment of properties of the new organism. Thus, a framework for safety assessment mainly depends on a range of differences in the genetic makeup of recipient and modified organism.

KEYWORDS

- **bacterial artificial chromosomes**
- **deoxyribonucleic acid**
- ***Escherichia coli***
- **mammalian artificial chromosomes**
- **P1-derived artificial chromosomes**
- **yeast artificial chromosome**

REFERENCES

Carter, M., & Shieh, J. C., (2015). *Guide to Research Techniques in Neuroscience*. Academic Press.

Chauthaiwale, V. M., Therwath, A., & Deshpande, V., (1992). Bacteriophage lambda as a cloning vector. *Microbiological Reviews, 56*(4), 577–591.

Collins, J., & Hohn, B., (1978). Cosmids: A type of plasmid gene-cloning vector that is packageable *in vitro* in bacteriophage lambda heads. *Proceedings of the National Academy of Sciences, 75*(9), 4242–4246.

Davies, K. M., (2007). Genetic modification of plant metabolism for human health benefits. *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, 622*(1, 2), 122–137.

Fári, M. G., & Kralovánszky, U. P., (2006). The founding father of biotechnology: Károly (Karl) ereky. *International Journal of Horticultural Science, 12*(1), 9–12.

Gupta, V., Sengupta, M., Prakash, J., & Tripathy, B. C., (2017). *Basic and Applied Aspects of Biotechnology*. Springer.

Hohn, B., & Murray, K., (1977). Packaging recombinant DNA molecules into bacteriophage particles *in vitro*. *Proceedings of the National Academy of Sciences, 74*(8), 3259–3263.
Maloy, S., & Hughes, K., (2013). *Brenner's Encyclopedia of Genetics*. Academic Press.
Mandel, M., & Higa, A., (1970). Calcium-dependent bacteriophage DNA infection. *Journal of Molecular Biology, 53*(1), 159–162.
Morange, M., (2000). *A History of Molecular Biology*. Harvard University Press.
Neumann, E., Schaefer-Ridder, M., Wang, Y., & Hofschneider, P., (1982). Gene transfer into mouse lyoma cells by electroporation in high electric fields. *The EMBO Journal, 1*(7), 841–845.
Newell, C. A., (2000). Plant transformation technology. *Molecular Biotechnology, 16*(1), 53–65.
O'Brien, J. A., & Lummis, S. C., (2011). Nano-biolistics: A method of biolistic transfection of cells and tissues using a gene gun with novel nanometer-sized projectiles. *BMC Biotechnology, 11*(1), 1–6.
Pearson, H., (2006). What is a gene? *Nature, 441*(7092), 398–402.
Robl, J., Kasinathan, P., Sullivan, E., Kuroiwa, Y., Tomizuka, K., & Ishida, I., (2003). Artificial chromosome vectors and expression of complex proteins in transgenic animals. *Theriogenology, 59*(1), 107–113.
Robl, J., Wang, Z., Kasinathan, P., & Kuroiwa, Y., (2007). Transgenic animal production and animal biotechnology. *Theriogenology, 67*(1), 127–133.
Williamson, J., (2012). *Dragon's Island*. Hachette UK.

Concepts of Genetic Engineering

Carter, M. , & Shieh, J. C. , (2015). Guide to Research Techniques in Neuroscience. Academic Press.
Chauthaiwale, V. M. , Therwath, A. , & Deshpande, V. , (1992). Bacteriophage lambda as a cloning vector. Microbiological Reviews, 56(4), 577–591.
Collins, J. , & Hohn, B. , (1978). Cosmids: A type of plasmid gene-cloning vector that is packageable in vitro in bacteriophage lambda heads. Proceedings of the National Academy of Sciences, 75(9), 4242–4246.
Davies, K. M. , (2007). Genetic modification of plant metabolism for human health benefits. Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, 622(1, 2), 122–137.
Fári, M. G. , & Kralovánszky, U. P. , (2006). The founding father of biotechnology: Károly (Karl) ereky. International Journal of Horticultural Science, 12(1), 9–12.
Gupta, V. , Sengupta, M. , Prakash, J. , & Tripathy, B. C. , (2017). Basic and Applied Aspects of Biotechnology. Springer.
Hohn, B. , & Murray, K. , (1977). Packaging recombinant DNA molecules into bacteriophage particles in vitro. Proceedings of the National Academy of Sciences, 74(8), 3259–3263.
Maloy, S. , & Hughes, K. , (2013). Brenner's Encyclopedia of Genetics. Academic Press.
Mandel, M. , & Higa, A. , (1970). Calcium-dependent bacteriophage DNA infection. Journal of Molecular Biology, 53(1), 159–162.
Morange, M. , (2000). A History of Molecular Biology. Harvard University Press.
Neumann, E. , Schaefer-Ridder, M. , Wang, Y. , & Hofschneider, P. , (1982). Gene transfer into mouse lyoma cells by electroporation in high electric fields. The EMBO Journal, 1(7), 841–845.
Newell, C. A. , (2000). Plant transformation technology. Molecular Biotechnology, 16(1), 53–65.
O'Brien, J. A. , & Lummis, S. C. , (2011). Nano-biolistics: A method of biolistic transfection of cells and tissues using a gene gun with novel nanometer-sized projectiles. BMC Biotechnology, 11(1), 1–6.
Pearson, H. , (2006). What is a gene? Nature, 441(7092), 398–402.
Robl, J. , Kasinathan, P. , Sullivan, E. , Kuroiwa, Y. , Tomizuka, K. , & Ishida, I. , (2003). Artificial chromosome vectors and expression of complex proteins in transgenic animals. Theriogenology, 59(1), 107–113.
Robl, J. , Wang, Z. , Kasinathan, P. , & Kuroiwa, Y. , (2007). Transgenic animal production and animal biotechnology. Theriogenology, 67(1), 127–133. Williamson, J., (2012). Dragon's Island. Hachette UK.

Enzymes of Genetic Engineering

Adereth, Y. , Champion, K. J. , Hsu, T. , & Dammai, V. , (2005). Site-directed mutagenesis using Pfu DNA polymerase and T4 DNA ligase. Biotechniques, 38(6), 864–868.
Allan, J. , Fraser, R. M. , Owen-Hughes, T. , & Keszenman-Pereyra, D. , (2012). Micrococcal nuclease does not substantially bias nucleosome mapping. Journal of Molecular Biology, 417(3), 152–164.
Alotaibi, A. , & Khan, J. , (2016). Kinetic study and basal media modification of cellulase enzyme production by mutated strain of Aspergillus fumigates (AF1) [Research]. International Journal of Pharma and Bio Sciences, 7(1), 193–200. https://www.ijpbs.net/abstract.php?article=NDg5Ng== (accessed on 12 October 2022).
Arber, W. , & Nathans, D. , (1992). In: Hamilton, O. Smith , (ed.), Physiology or Medicine, 1971–1980, 469.
Archer, D. B. , & Peberdy, J. F. , (1997). The molecular biology of secreted enzyme production by fungi. Critical Reviews in Biotechnology, 17(4), 273–306.
Artursson, V. , Finlay, R. D. , & Jansson, J. K. , (2005). Combined bromodeoxyuridine immunocapture and terminal-restriction fragment length polymorphism analysis highlights

differences in the active soil bacterial metagenome due to Glomus mosseae inoculation or plant species. Environmental Microbiology, 7(12), 1952–1966.
Aubry, A. , Fisher, L. M. , Jarlier, V. , & Cambau, E. , (2006). First functional characterization of a singly expressed bacterial type II topoisomerase: The enzyme from Mycobacterium tuberculosis. Biochemical and Biophysical Research Communications, 348(1), 158–165.
Avalle, B. , Friboulet, A. , & Thomas, D. , (2000). Enzymes and abzymes relationships. Journal of Molecular Catalysis B: Enzymatic, 10(1–3), 39–45.
Bandele, O. J. , & Osheroff, N. , (2007). Bioflavonoids as poisons of human topoisomerase IIα and IIβ. Biochemistry, 46(20), 6097–6108.
Barakat, K. H. , Gajewski, M. M. , & Tuszynski, J. A. , (2012). DNA polymerase beta (polβ) inhibitors: A comprehensive overview. Drug Discovery Today, 17(15, 16), 913–920.
Beadell, J. S. , & Fleischer, R. C. , (2005). A restriction enzyme-based assay to distinguish between avian haemosporidian. Journal of Parasitology, 91(3), 683–685.
Beard, W. A. , & Wilson, S. H. , (2006). Structure and mechanism of DNA polymerase β. Chemical Reviews, 106(2), 361–382.
Bilska, A. , Kusio-Kobiałka, M. , Krawczyk, P. S. , Gewartowska, O. , Tarkowski, B. , Kobyłecki, K. , Nowis, D. , et al. , (2020). Immunoglobulin expression and the humoral immune response is regulated by the non-canonical poly (A) polymerase TENT5C. Nature Communications, 11(1), 1–17.
Blatter, N. , Bergen, K. , Nolte, O. , Welte, W. , Diederichs, K. , Mayer, J. , Wieland, M. , & Marx, A. , (2013). Structure and function of an RNA-reading thermostable DNA polymerase. Angewandte Chemie International Edition, 52(45), 11935–11939.
Boado, R. J. , Zhang, Y. , Zhang, Y. , Xia, C. F. , Wang, Y. , & Pardridge, W. M. , (2008). Genetic engineering of a lysosomal enzyme fusion protein for targeted delivery across the human blood-brain barrier. Biotechnology and Bioengineering, 99(2), 475–484.
Borchert, G. M. , Lanier, W. , & Davidson, B. L. , (2006). RNA polymerase III transcribes human microRNAs. Nature Structural & Molecular Biology, 13(12), 1097–1101.
Boriack-Sjodin, P. A. , & Swinger, K. K. , (2016). Protein methyltransferases: A distinct, diverse, and dynamic family of enzymes. Biochemistry, 55(11), 1557–1569.
Bratic, A. , Kauppila, T. E. , Macao, B. , Grönke, S. , Siibak, T. , Stewart, J. B. , Baggio, F. , et al. , (2015). Complementation between polymerase-and exonuclease-deficient mitochondrial DNA polymerase mutants in genomically engineered flies. Nature Communications, 6(1), 1–15.
Bukowski, M. , Polakowska, K. , Ilczyszyn, W. M. , Sitarska, A. , Nytko, K. , Kosecka, M. , Miedzobrodzki, J. , et al. , (2015). Species determination within Staphylococcus genus by extended PCR-restriction fragment length polymorphism of saoC gene. FEMS Microbiology Letters, 362(1), 1–11.
Camilloni, C. , Robustelli, P. , Simone, A. D. , Cavalli, A. , & Vendruscolo, M. , (2012). Characterization of the conformational equilibrium between the two major substrates of RNase A using NMR chemical shifts. Journal of the American Chemical Society, 134(9), 3968–3971.
Chander, Y. , Koelbl, J. , Puckett, J. , Moser, M. J. , Klingele, A. J. , Liles, M. R. , Carrias, A. , et al., (2014). A novel thermostable polymerase for RNA and DNA loop-mediated isothermal amplification (LAMP). Frontiers in Microbiology, 5, 395.
Choi, W. S. , Ha, D. , Park, S. , & Kim, T. , (2011). Synthetic multicellular cell-to-cell communication in inkjet printed bacterial cell systems. Biomaterials, 32(10), 2500–2507.
Church, D. N. , Briggs, S. E. , Palles, C. , Domingo, E. , Kearsey, S. J. , Grimes, J. M. , Gorman, M. , et al. , (2013). DNA polymerase ε and δ exonuclease domain mutations in endometrial cancer. Human Molecular Genetics, 22(14), 2820–2828.
Cornish-Bowden, A. , (2014). Current IUBMB recommendations on enzyme nomenclature and kinetics. Perspectives in Science, 1(1–6), 74–87.
Didenko, V. V. , (2011). In situ labeling of DNA breaks and apoptosis by t7 DNA polymerase. In: DNA Damage Detection in Situ, Ex Vivo, and in Vivo (pp. 37–48). Springer.
Dieci, G. , Fiorino, G. , Castelnuovo, M. , Teichmann, M. , & Pagano, A. , (2007). The expanding RNA polymerase III transcriptome. Trends in Genetics, 23(12), 614–622.
Durbecq, V. , Desmed, C. , Paesmans, M. , Cardoso, F. , Di Leo, A. , Mano, M. , Rouas, G. , et al. , (2004). Correlation between topoisomerase-IIα gene amplification and protein

expression in HER-2 amplified breast cancer. International Journal of Oncology, 25(5), 1473–1479.
Eid, J. , Fehr, A. , Gray, J. , Luong, K. , Lyle, J. , Otto, G. , Peluso, P. , et al. , (2009). Real-time DNA sequencing from single polymerase molecules. Science, 323(5910), 133–138.
Etson, C. M. , Hamdan, S. M. , Richardson, C. C. , & Van, O. A. M. , (2010). Thioredoxin suppresses microscopic hopping of T7 DNA polymerase on duplex DNA. Proceedings of the National Academy of Sciences, 107(5), 1900–1905.
Fernandez-Leiro, R. , Conrad, J. , Scheres, S. H. , & Lamers, M. H. , (2015). Cryo-EM structures of the E. coli replicative DNA polymerase reveal its dynamic interactions with the DNA sliding clamp, exonuclease and τ. Elife, 4, e11134.
Galperin, M. Y. , (2008). The molecular biology database collection: 2008 update. Nucleic Acids Research, 36(suppl_1), D2–D4.
Garcia-Bonete, M. J. , Jensen, M. , & Katona, G. , (2019). A practical guide to developing virtual and augmented reality exercises for teaching structural biology. Biochemistry and Molecular Biology Education, 47(1), 16–24.
Ghosh, S. , Marintcheva, B. , Takahashi, M. , & Richardson, C. C. , (2009). C-terminal phenylalanine of bacteriophage T7 single-stranded DNA-binding protein is essential for strand displacement synthesis by T7 DNA polymerase at a nick in DNA. Journal of Biological Chemistry, 284(44), 30339–30349.
Gibson, D. G. , Glass, J. I. , Lartigue, C. , Noskov, V. N. , Chuang, R. Y. , Algire, M. A. , Benders, G. A. , et al. , (2010). Creation of a bacterial cell controlled by a chemically synthesized genome. Science, 329(5987), 52–56.
Ginsberg, S. D. , & Che, S. , (2014). Methods and compositions for amplification and detection of microRNAs (miRNAs) and noncoding RNAs (ncRNAs) using the signature sequence amplification method (SSAM). Recent Advances in DNA & Gene Sequences (Formerly Recent Patents on DNA & Gene Sequences), 8(1), 2–9.
Glass, J. I. , (2012). Synthetic genomics and the construction of a synthetic bacterial cell. Perspectives in Biology and Medicine, 55(4), 473–489.
Gloeckner, C. , Sauter, K. B. , & Marx, A. , (2007). Evolving a thermostable DNA polymerase that amplifies from highly damaged templates. Angewandte Chemie International Edition, 46(17), 3115–3117.
Graham, C. F. , Glenn, T. C. , McArthur, A. G. , Boreham, D. R. , Kieran, T. , Lance, S. , Manzon, R. G. , et al. , (2015). Impacts of degraded DNA on restriction enzyme associated DNA sequencing (RADS eq). Molecular Ecology Resources, 15(6), 1304–1315.
Gupta, R. , Xu, S. Y. , Sharma, P. , & Capalash, N. , (2012). Characterization of MspNI (G/GWCC) and MspNII (R/GATCY), novel thermostable type II restriction endonucleases from Meiothermus sp., isoschizomers of AvaII and BstYI. Molecular Biology Reports, 39(5), 5607–5614.
Hamza, T. A. , (2017). Bacterial protease enzyme: Safe and good alternative for industrial and commercial use. Int. J. Chem. Biomol. Sci, 3(1), 1–10.
Hanke, T. , Ramiro, M. J. , Trigueros, S. , Roca, J. , & Larraga, V. , (2003). Cloning, functional analysis and post-transcriptional regulation of a type II DNA topoisomerase from Leishmania infantum. A new potential target for anti-parasite drugs. Nucleic Acids Research, 31(16), 4917–4928.
Hariharan, C. , & Reha-Krantz, L. J. , (2005). Using 2-Aminopurine fluorescence to detect bacteriophage T4 DNA polymerase− DNA complexes that are important for primer extension and proofreading reactions. Biochemistry, 44(48), 15674–15684.
Hernandez, A. J. , Lee, S. J. , Chang, S. , Lee, J. A. , Loparo, J. J. , & Richardson, C. C. , (2020). Catalytically inactive T7 DNA polymerase imposes a lethal replication roadblock. Journal of Biological Chemistry, 295(28), 9542–9550.
Janda, K. D. , Weinhouse, M. I. , Danon, T. , Pacelli, K. A. , & Schloeder, D. M. , (1991). Antibody bait and switch catalysis: A survey of antigens capable of inducing abzymes with acyl-transfer properties. Journal of the American Chemical Society, 113(14), 5427–5434.
Jayaprakash, A. D. , Jabado, O. , Brown, B. D. , & Sachidanandam, R. , (2011). Identification and remediation of biases in the activity of RNA ligases in small-RNA deep sequencing. Nucleic Acids Research, 39(21), e141.

Johnson, D. E. , Takahashi, M. , Hamdan, S. M. , Lee, S. J. , & Richardson, C. C. , (2007). Exchange of DNA polymerases at the replication fork of bacteriophage T7. Proceedings of the National Academy of Sciences, 104(13), 5312–5317.
Johnson, S. A. , Dubeau, L. , & Johnson, D. L. , (2008). Enhanced RNA polymerase III-dependent transcription is required for oncogenic transformation. Journal of Biological Chemistry, 283(28), 19184–19191.
Kanaras, A. G. , Wang, Z. , Hussain, I. , Brust, M. , Cosstick, R. , & Bates, A. D. , (2007). Site-specific ligation of DNA-modified gold nanoparticles activated by the restriction enzyme styI. Small, 3(1), 67–70.
Khan, J. , Alotaibi, A. , & Deka, M. , (2015). Effect of colchicine induced mutation on cellulose enzyme production by Aspergillus fumigatus. World J Pharmaceutical Res., 4, 461–471.
Kiedrowski, M. R. , Crosby, H. A. , Hernandez, F. J. , Malone, C. L. , McNamara, II. J. O. , & Horswill, A. R. , (2014). Staphylococcus aureus Nuc2 is a functional, surface-attached extracellular nuclease. PloS One, 9(4), e95574.
Kim, J. E. , Huang, R. , Chen, H. , You, C. , & Zhang, Y. H. P. , (2016). Facile construction of random gene mutagenesis library for directed evolution without the use of restriction enzyme in Escherichia coli. Biotechnology Journal, 11(9), 1142–1150.
Kubista, M. , Andrade, J. M. , Bengtsson, M. , Forootan, A. , Jonák, J. , Lind, K. , Sindelka, R. , et al. , (2006). The real-time polymerase chain reaction. Molecular Aspects of Medicine, 27(2, 3), 95–125.
Lange, S. S. , Takata, K. I. , & Wood, R. D. , (2011). DNA polymerases and cancer. Nature Reviews Cancer, 11(2), 96–110.
Laskin, A. I. , Mosbach, K. , Thomas, D. , & Wingard, L. B. , (1987). Enzyme Engineering, 8.
Le, Y. , Chen, H. , Zagursky, R. , Wu, J. D. , & Shao, W. , (2013). Thermostable DNA ligasemediated PCR production of circular plasmid (PPCP) and its application in directed evolution via in situ error-prone PCR. DNA Research, 20(4), 375–382.
Lin, D. , & O'Callaghan, C. A. , (2018). MetClo: Methylase-assisted hierarchical DNA assembly using a single type IIS restriction enzyme. Nucleic Acids Research, 46(19), e113.
Loenen, W. A. , Dryden, D. T. , Raleigh, E. A. , & Wilson, G. G. , (2014). Type I restriction enzymes and their relatives. Nucleic Acids Research, 42(1), 20–44.
Lohman, G. J. , Tabor, S. , & Nichols, N. M. , (2011). DNA ligases. Current Protocols in Molecular Biology, 94(1), 3.14. 11–13.14. 17.
Luo, G. , Wang, M. , Konigsberg, W. H. , & Xie, X. S. , (2007). Single-molecule and ensemble fluorescence assays for a functionally important conformational change in T7 DNA polymerase. Proceedings of the National Academy of Sciences, 104(31), 12610–12615.
Makarova, K. S. , Wolf, Y. I. , & Koonin, E. V. , (2018). Classification and nomenclature of CRISPR-Cas systems: Where from here? The CRISPR Journal, 1(5), 325–336.
Meroueh, S. O. , Bencze, K. Z. , Hesek, D. , Lee, M. , Fisher, J. F. , Stemmler, T. L. , & Mobashery, S. , (2006). Three-dimensional structure of the bacterial cell wall peptidoglycan. Proceedings of the National Academy of Sciences, 103(12), 4404–4409.
Mohammadi, R. , Abastabar, M. , Mirhendi, H. , Badali, H. , Shadzi, S. , Chadeganipour, M. , Pourfathi, P. , et al. , (2015). Use of restriction fragment length polymorphism to rapidly identify dermatophyte species related to dermatophytosis. Jundishapur Journal of Microbiology, 8(6).
Montaner, B. , Castillo-Avila, W. , Martinell, M. , Öllinger, R. , Aymami, J. , Giralt, E. , & Pérez-Tomás, R. , (2005). DNA interaction and dual topoisomerase I and II inhibition properties of the anti-tumor drug prodigiosin. Toxicological Sciences, 85(2), 870–879.
Moser, M. J. , DiFrancesco, R. A. , Gowda, K. , Klingele, A. J. , Sugar, D. R. , Stocki, S. , Mead, D. A. , & Schoenfeld, T. W. , (2012). Thermostable DNA polymerase from a viral metagenome is a potent RT-PCR enzyme. PloS One, 7(6), e38371.
Muse, G. W. , Gilchrist, D. A. , Nechaev, S. , Shah, R. , Parker, J. S. , Grissom, S. F. , Zeitlinger, J. , & Adelman, K. , (2007). RNA polymerase is poised for activation across the genome. Nature Genetics, 39(12), 1507–1511.
Nei, M. , & Tajima, F. , (1981). DNA polymorphism detectable by restriction endonucleases. Genetics, 97(1), 145–163.
Nevinsky, G. A. , & Buneva, V. N. , (2005). Natural catalytic antibodies—Abzymes. Catalytic Antibodies, 503–567.

Nishida, H. , Mayanagi, K. , Kiyonari, S. , Sato, Y. , Oyama, T. , Ishino, Y. , & Morikawa, K. , (2009). Structural determinant for switching between the polymerase and exonuclease modes in the PCNA-replicative DNA polymerase complex. Proceedings of the National Academy of Sciences, 106(49), 20693–20698.
Nørskov-Lauritsen, N. , Claesson, R. , Jensen, A. B. , Åberg, C. H. , & Haubek, D. , (2019). Aggregatibacter actinomycetemcomitans: Clinical significance of a pathobiont subjected to ample changes in classification and nomenclature. Pathogens, 8(4), 243.
Paterson, A. H. , Freeling, M. , Tang, H. , & Wang, X. , (2010). Insights from the comparison of plant genome sequences. Annual Review of Plant Biology, 61, 349–372.
Pech, A. , Achenbach, J. , Jahnz, M. , Schülzchen, S. , Jarosch, F. , Bordusa, F. , & Klussmann, S. , (2017). A thermostable d-polymerase for mirror-image PCR. Nucleic Acids Research, 45(7), 3997–4005.
Pellicanò, G. , Al Mamun, M. , Jurado-Santiago, D. , Villa-Hernández, S. , Yin, X. , Giannattasio, M. , Lanz, M. C. , et al., (2021). Checkpoint-mediated DNA polymerase ε exonuclease activity curbing counteracts resection-driven fork collapse. Molecular Cell.
Pingoud, A. , & Jeltsch, A. , (2001). Structure and function of type II restriction endonucleases. Nucleic Acids Research, 29(18), 3705–3727.
Pingoud, A. , Fuxreiter, M. , Pingoud, V. , & Wende, W. , (2005). Type II restriction endonucleases: Structure and mechanism. Cellular and Molecular Life Sciences, 62(6), 685–707.
Pommier, Y. , (2006). Topoisomerase I inhibitors: Camptothecins and beyond. Nature Reviews Cancer, 6(10), 789–802.
Poulsen, N. , Berne, C. , Spain, J. , & Kroeger, N. , (2007). Silica immobilization of an enzyme through genetic engineering of the diatom Thalassiosira pseudonana. Angewandte Chemie International Edition, 46(11), 1843–1846.
Qi, R. , & Otting, G. , (2019). Mutant T4 DNA polymerase for easy cloning and mutagenesis. PloS One, 14(1), e0211065.
Rezaei-Matehkolaei, A. , Makimura, K. , Shidfar, M. , Zaini, F. , Eshraghian, M. , Jalalizand, N. , Nouripour-Sisakht, S. , et al. , (2012). Use of single-enzyme PCR-restriction digestion barcode targeting the internal transcribed spacers (ITS RDNA) to identify dermatophyte species. Iranian Journal of Public Health, 41(3), 82.
Ricard, M. , (2005). Approaches Used to Better Understand the Functions of the Complex. (AVS). Marine Chemistry, 97(3–4), 141–197.
Rigoldi, F. , Donini, S. , Redaelli, A. , Parisini, E. , & Gautieri, A. , (2018). Engineering of thermostable enzymes for industrial applications. APL Bioengineering, 2(1), 011501.
Roberts, R. J. , Vincze, T. , Posfai, J. , & Macelis, D. , (2005). REBASE—Restriction enzymes and DNA methyltransferases. Nucleic Acids Research, 33(suppl_1), D230–D232.
Roether, J. , Chu, K. Y. , Willenbacher, N. , Shen, A. Q. , & Bhalla, N. , (2019). Real-time monitoring of DNA immobilization and detection of DNA polymerase activity by a microfluidic nanoplasmonic platform. Biosensors and Bioelectronics, 142, 111528.
Rosenberg, H. F. , (2008). RNase A ribonucleases and host defense: An evolving story. Journal of Leukocyte Biology, 83(5), 1079–1087.
Ruiz-Avila, L. B. , Huecas, S. , Artola, M. , Vergonõs, A. , Ramírez-Aportela, E. , Cercenado, E. , Barasoain, I. , et al. , (2013). Synthetic inhibitors of bacterial cell division targeting the GTP-binding site of FtsZ. ACS Chemical Biology, 8(9), 2072–2083.
Ruiz-García, L. , Cabezas, J. A. , De María, N. , & Cervera, M. T. , (2010). Isoschizomers and amplified fragment length polymorphism for the detection of specific cytosine methylation changes. In: Plant Epigenetics (pp. 63–74). Springer.
Ryu, J. , & Rowsell, E. , (2008). Quick identification of type I restriction enzyme isoschizomers using newly developed pTypeI and reference plasmids. Nucleic Acids Research, 36(13), e81–e81.
Salerno, S. , Da Settimo, F. , Taliani, S. , Simorini, F. , La Motta, C. , Fornaciari, G. , & Marini, A. M. , (2010). Recent advances in the development of dual topoisomerase I and II inhibitors as anticancer drugs. Current Medicinal Chemistry, 17(35), 4270–4290.
Sato, S. , & Takenaka, S. , (2014). Highly sensitive nuclease assays based on chemically modified DNA or RNA. Sensors, 14(7), 12437–12450.

Sauter, K. B. , & Marx, A. , (2006). Evolving thermostable reverse transcriptase activity in a DNA polymerase scaffold. Angewandte Chemie International Edition, 45(45), 7633–7635.

Sengupta, S. , Spiering, M. M. , Dey, K. K. , Duan, W. , Patra, D. , Butler, P. J. , Astumian, R. D. , et al. , (2014). DNA polymerase as a molecular motor and pump. ACS Nano, 8(3), 2410–2418.

Sharma, B. , Dangi, A. K. , & Shukla, P. , (2018). Contemporary enzyme based technologies for bioremediation: A review. Journal of Environmental Management, 210, 10–22.

Shinbrot, E. , Henninger, E. E. , Weinhold, N. , Covington, K. R. , Göksenin, A. Y. , Schultz, N. , Chao, H. , et al. , (2014). Exonuclease mutations in DNA polymerase epsilon reveal replication strand specific mutation patterns and human origins of replication. Genome Research, 24(11), 1740–1750.

Shuman, S. , (2009). DNA ligases: Progress and prospects. Journal of Biological Chemistry, 284(26), 17365–17369.

Silva, L. , & Antunes, A. , (2017). Vomeronasal receptors in vertebrates and the evolution of pheromone detection. Annual Review of Animal Biosciences, 5, 353–370.

Stano, N. M. , Jeong, Y. J. , Donmez, I. , Tummalapalli, P. , Levin, M. K. , & Patel, S. S. , (2005). DNA synthesis provides the driving force to accelerate DNA unwinding by a helicase. Nature, 435(7040), 370–373.

Terletskiy, V. , Tyshchenko, V. , Myrzakozha, D. , Zhanserkenova, O. , Ussenbekov, Y. , & Adaev, N. L. , (2014). Development of the double digest selective label (DDSL) typing technique and its application to Staphylococcus aureus epidemiology. Sains Malaysiana, 43(12), 1965–1972.

Terpe, K. , (2013). Overview of thermostable DNA polymerases for classical PCR applications: From molecular and biochemical fundamentals to commercial systems. Applied Microbiology and Biotechnology, 97(24), 10243–10254.

Tomkinson, A. E. , Vijayakumar, S. , Pascal, J. M. , & Ellenberger, T. , (2006). DNA ligases: Structure, reaction mechanism, and function. Chemical Reviews, 106(2), 687–699.

Tóth, E. , Huszár, K. , Bencsura, P. , Kulcsár, P. I. , Vodicska, B. , Nyeste, A. , Welker, Z. , et al. , (2014). Restriction enzyme body doubles and PCR cloning: On the general use of type IIs restriction enzymes for cloning. PloS One, 9(3), e90896.

Treacy, D. J. , Sankaran, S. M. , Gordon-Messer, S. , Saly, D. , Miller, R. , Isaac, S. R. , & Kosinski-Collins, M. S. , (2011). Implementation of a project-based molecular biology laboratory emphasizing protein structure-function relationships in a large introductory biology laboratory course. CBE—Life Sciences Education, 10(1), 18–24.

Treusch, A. H. , Vergin, K. L. , Finlay, L. A. , Donatz, M. G. , Burton, R. M. , Carlson, C. A. , & Giovannoni, S. J. , (2009). Seasonality and vertical structure of microbial communities in an ocean gyre. The ISME Journal, 3(10), 1148–1163.

Tropp, B. E. , (2012). Molecular Biology: Genes to Proteins. Jones & Bartlett Publishers.

Tsai, Y. C. , & Johnson, K. A. , (2006). A new paradigm for DNA polymerase specificity. Biochemistry, 45(32), 9675–9687.

Turner, P. , Mamo, G. , & Karlsson, E. N. , (2007). Potential and utilization of thermophiles and thermostable enzymes in biorefining. Microbial Cell Factories, 6(1), 1–23.

Van, B. J. B. , & Li, Z. , (2002). Enzyme technology: An overview. Current Opinion in Biotechnology, 13(4), 338–344.

Wang, L. , Yu, X. , Hu, P. , Broyde, S. , & Zhang, Y. , (2007). A water-mediated and substrateassisted catalytic mechanism for Sulfolobus solfataricus DNA polymerase IV. Journal of the American Chemical Society, 129(15), 4731–4737.

Wang, Y. , Li, B. , Liu, J. , & Zhou, H. , (2019). T4 DNA polymerase-assisted upgrade of a nicking/polymerization amplification strategy for ultrasensitive electrochemical detection of watermelon mosaic virus. Analytical and Bioanalytical Chemistry, 411(13), 2915–2924.

Watson, J. D. , (2012). The Polymerase Chain Reaction. Springer Science & Business Media.

White, H. B. , Benore, M. A. , Sumter, T. F. , Caldwell, B. D. , & Bell, E. , (2013). What skills should students of undergraduate biochemistry and molecular biology programs have upon graduation? Biochemistry and Molecular Biology Education, 41(5), 297–301.

Wilson, K. , & Walker, J. , (2010). Principles and Techniques of Biochemistry and Molecular Biology. Cambridge University Press.

Xu, W. , Jiang, W. , Wang, J. , Yu, L. , Chen, J. , Liu, X. , Liu, L. , & Zhu, T. F. , (2017). Total chemical synthesis of a thermostable enzyme capable of polymerase chain reaction. Cell Discovery, 3(1), 1–10.
Zahurancik, W. J. , & Suo, Z. , (2020). Kinetic investigation of the polymerase and exonuclease activities of human DNA polymerase ε holoenzyme. Journal of Biological Chemistry, 295(50), 17251–17264.
Zumbach, J. , Schmitt, S. , Reimann, P. , & Starkloff, P. , (2006). Learning life sciences: Design and development of a virtual molecular biology learning lab. Journal of Computers in Mathematics and Science Teaching, 25(3), 281–300.

Tools Used in Genetic Engineering

Akram, M. , Jabeen, F. , Daniyal, M. , Zainab, R. , Ul Haq, U. , Adetunji, C. O. , Egbuna, C. , et al., (2020). Genetic engineering of novel products of health significance: Recombinant DNA technology. In: Functional Foods and Nutraceuticals (pp. 595–611). Springer.
Al-Banaa, K. , Alhillan, A. , Hawa, F. , Mahmood, R. , Zaki, A. , El Abdallah, M. , El Jack, A. , et al., (2019). Emicizumab use in treatment of acquired hemophilia A: A case report. The American Journal of Case Reports, 20, 1046.
Al-Hakim, A. , Escribano-Diaz, C. , Landry, M. C. , O'Donnell, L. , Panier, S. , Szilard, R. K. , & Durocher, D. , (2010). The ubiquitous role of ubiquitin in the DNA damage response. DNA Repair, 9(12), 1229–1240.
Alomari, A. , (2018). Biophysical and Kinetic Analysis of Escherichia coli DNA Ligase Activity and Inhibition. University of Portsmouth].
Anastasakis, D. , Skeparnias, I. , Shaukat, A. N. , Grafanaki, K. , Kanellou, A. , Taraviras, S. , Papachristou, D. J. , et al. , (2016). Mammalian PNLDC1 is a novel poly (A) specific exonuclease with discrete expression during early development. Nucleic Acids Research, 44(18), 8908–8920.
Andrup, L. , & Andersen, K. , (1999). A comparison of the kinetics of plasmid transfer in the conjugation systems encoded by the F plasmid from Escherichia coli and plasmid pCF10 from Enterococcus faecalis. Microbiology, 145(8), 2001–2009.
Aneesh, T. , Sekhar, S. , Jose, A. , Chandran, L. , & Zachariah, S. M. , (2009). Pharmacogenomics: The right drug to the right person. Journal of Clinical Medicine Research, 1(4), 191.
Aneja, B. , Yadav, N. R. , Chawla, V. , & Yadav, R. C. , (2012). Sequence-related amplified polymorphism (SRAP) molecular marker system and its applications in crop improvement. Molecular Breeding, 30(4), 1635–1648.
Ashok, N. A. , Spoorthi, B. K. , Ashcheulova, T. , & Gerasimchuk, N. , (2015). Genetic Engineering and Ethical Issues (Doctoral dissertation).
Autexier, C. , & Lue, N. F. , (2006). The structure and function of telomerase reverse transcriptase. Annu. Rev. Biochem., 75, 493–517.
Baeshen, N. A. , Baeshen, M. N. , Sheikh, A. , Bora, R. S. , Ahmed, M. M. M. , Ramadan, H. A. , Saini, K. S. , & Redwan, E. M. , (2014). Cell factories for insulin production. Microbial Cell Factories, 13(1), 1–9.
Balbás, P. , Soberón, X. , Merino, E. , Zurita, M. , Lomeli, H. , Valle, F. , Flores, N. , & Bolivar, F. , (1986). Plasmid vector pBR322 and its special-purpose derivatives: A review. Gene, 50(1–3), 3–40.
Baltimore, D. , Berg, P. , Botchan, M. , Carroll, D. , Charo, R. A. , Church, G. , Corn, J. E. , et al. , (2015). A prudent path forward for genomic engineering and germline gene modification. Science, 348(6230), 36–38.
Barra, V. , & Fachinetti, D. , (2018). The dark side of centromeres: Types, causes and consequences of structural abnormalities implicating centromeric DNA. Nature Communications, 9(1), 1–17.
Barrie, J. , Zawdie, G. , & João, E. , (2019). Assessing the role of triple helix system intermediaries in nurturing an industrial biotechnology innovation network. Journal of Cleaner Production, 214, 209–223.

Bekana, G. , (2017). Review on Application of Genetic Engineering to Crop Improvement and Its Perceptions in Ethiopia. Advances in Life Science and Technolog. 60, 1–7.
Bera, R. K. , (2009). The story of the Cohen–Boyer patents. Current Science, 96(6), 760–763.
Berg, P. , & Mertz, J. E. , (2010). Personal reflections on the origins and emergence of recombinant DNA technology. Genetics, 184(1), 9–17.
Bernstein, N. K. , Williams, R. S. , Rakovszky, M. L. , Cui, D. , Green, R. , Karimi-Busheri, F. , Mani, R. S. , et al. , (2005). The molecular architecture of the mammalian DNA repair enzyme, polynucleotide kinase. Molecular Cell, 17(5), 657–670.
Blaise, D. , Venugopalan, M. , & Raju, A. , (2014). Introduction of Bt cotton hybrids in India: Did it change the agronomy? Indian Journal of Agronomy, 59(1), 1–20.
Blum, A. , (2011). Drought resistance–is it really a complex trait? Functional Plant Biology, 38(10), 753–757.
Bouzidi, M. F. , Franchel, J. , Tao, Q. , Stormo, K. , Mraz, A. , Nicolas, P. , & Mouzeyar, S. , (2006). A sunflower BAC library suitable for PCR screening and physical mapping of targeted genomic regions. Theoretical and Applied Genetics, 113(1), 81–89.
Branã, A. F. , Rodríguez, M. , Pahari, P. , Rohr, J. , García, L. A. , & Blanco, G. , (2014). Activation and silencing of secondary metabolites in Streptomyces albus and Streptomyces lividans after transformation with cosmids containing the thienamycin gene cluster from Streptomyces cattleya. Archives of Microbiology, 196(5), 345–355.
Burke, D. T. , Carle, G. F. , & Olson, M. V. , (1987). Cloning of large segments of exogenous DNA into yeast by means of artificial chromosome vectors. Science, 236(4803), 806–812.
Carter, P. J. , (2011). Introduction to current and future protein therapeutics: A protein engineering perspective. Experimental Cell Research, 317(9), 1261–1269.
Casadaban, M. J. , & Cohen, S. N. , (1980). Analysis of gene control signals by DNA fusion and cloning in Escherichia coli. Journal of Molecular Biology, 138(2), 179–207.
Castaman, G. , & Linari, S. , (2016). Human von Willebrand factor/factor VIII concentrates in the management of pediatric patients with von Willebrand disease/hemophilia A. Therapeutics and Clinical Risk Management, 12, 1029.
Chandler, M. , De La Cruz, F. , Dyda, F. , Hickman, A. B. , Moncalian, G. , & Ton-Hoang, B. , (2013). Breaking and joining single-stranded DNA: The HUH endonuclease superfamily. Nature Reviews Microbiology, 11(8), 525–538.
Cheng, J. , Pinnell, L. , Engel, K. , Neufeld, J. D. , & Charles, T. C. , (2014). Versatile broadhost-range cosmids for construction of high quality metagenomic libraries. Journal of Microbiological Methods, 99, 27–34.
Ching, K. H. , Collarini, E. J. , Abdiche, Y. N. , Bedinger, D. , Pedersen, D. , Izquierdo, S. , Harriman, R. , et al. , (2018). Chickens with humanized immunoglobulin genes generate antibodies with high affinity and broad epitope coverage to conserved targets. mAbs.
Cradick, T. J. , Keck, K. , Bradshaw, S. , Jamieson, A. C. , & McCaffrey, A. P. , (2010). Zincfinger nucleases as a novel therapeutic strategy for targeting hepatitis B virus DNAs. Molecular Therapy, 18(5), 947–954.
Crampton, N. , Yokokawa, M. , Dryden, D. T. , Edwardson, J. M. , Rao, D. N. , Takeyasu, K. , Yoshimura, S. H. , & Henderson, R. M. , (2007). Fast-scan atomic force microscopy reveals that the type III restriction enzyme EcoP15I is capable of DNA translocation and looping. Proceedings of the National Academy of Sciences, 104(31), 12755–12760.
D'Herelle, F. , & Smith, G. H. , (1926). The Bacteriophage and Its Behavior. Am Assoc Immnol.
Depositario, D. P. T. , Nayga, J. , Rodolfo, M. , Wu, X. , & Laude, T. P. , (2009). Effects of information on consumers' willingness to pay for golden rice. Asian Economic Journal, 23(4), 457–476.
Dunbar, C. E. , High, K. A. , Joung, J. K. , Kohn, D. B. , Ozawa, K. , & Sadelain, M. , (2018). Gene therapy comes of age. Science, 359(6372).
Engler, C. , Gruetzner, R. , Kandzia, R. , & Marillonnet, S. , (2009). Golden gate shuffling: A one-pot DNA shuffling method based on type IIs restriction enzymes. PloS One, 4(5), e5553.
Flores, J. L. , (2019). Genetic Engineering in Agriculture. Library of Parliament= Bibliothèque du Parlement.

Franchini, M. , & Lippi, G. , (2010). Von Willebrand factor-containing factor VIII concentrates and inhibitors in haemophilia A. Thrombosis and Haemostasis, 104(11), 931–940.
Friedberg, E. C. , Lehmann, A. R. , & Fuchs, R. P. , (2005). Trading places: How do DNA polymerases switch during translesion DNA synthesis? Molecular Cell, 18(5), 499–505.
Haeusler, R. A. , Astiarraga, B. , Camastra, S. , Accili, D. , & Ferrannini, E. , (2013). Human insulin resistance is associated with increased plasma levels of 12α-hydroxylated bile acids. Diabetes, 62(12), 4184–4191.
Hiraga, S. , Jaffe, A. , Ogura, T. , Mori, H. , & Takahashi, H. , (1986). F plasmid ccd mechanism in Escherichia coli. Journal of Bacteriology, 166(1), 100–104.
Holst-Jensen, A. , (2009). Testing for genetically modified organisms (GMOs): Past, present and future perspectives. Biotechnology Advances, 27(6), 1071–1082.
Houdebine, L. M. , (2009). Production of pharmaceutical proteins by transgenic animals. Comparative Immunology, Microbiology and Infectious Diseases, 32(2), 107–121.
Hummel, A. W. , Doyle, E. L. , & Bogdanove, A. J. , (2012). Addition of transcription activator-like effector binding sites to a pathogen strain-specific rice bacterial blight resistance gene makes it effective against additional strains and against bacterial leaf streak. New Phytologist, 195(4), 883–893.
Islam, M. , (2013). Animal models of diabetic neuropathy: Progress since 1960s. Journal of Diabetes Research, 2013.
Kempton, C. L. , & White, G. C. , (2009). How we treat a hemophilia A patient with a factor VIII inhibitor. Blood, The Journal of the American Society of Hematology, 113(1), 11–17.
Khush, G. S. , (2013). Strategies for increasing the yield potential of cereals: Case of rice as an example. Plant Breeding, 132(5), 433–436.
Kulvir, S. , Vikas, J. , Vikram, S. , & Rathore, P. , (2007). Performance of Bt cotton hybrids under different geometrical arrangements. Journal of Cotton Research and Development, 21(1), 41–44.
Lal, P. , Ramachandran, V. , Goyal, R. , & Sharma, R. , (2007). Edible vaccines: Current status and future. Indian J. Med. Microbiol., 25(2), 93–102.
Lambert, T. , Benson, G. , Dolan, G. , Hermans, C. , Jiménez-Yuste, V. , Ljung, R. , Morfini, M. , et al. , (2018). Practical aspects of extended half-life products for the treatment of haemophilia. Therapeutic Advances in Hematology, 9(9), 295–308.
Langer, K. , Anhorn, M. , Steinhauser, I. , Dreis, S. , Celebi, D. , Schrickel, N. , Faust, S. , & Vogel, V. , (2008). Human serum albumin (HSA) nanoparticles: Reproducibility of preparation process and kinetics of enzymatic degradation. International Journal of Pharmaceutics, 347(1, 2), 109–117.
Leader, B. , Baca, Q. J. , & Golan, D. E. , (2008). Protein therapeutics: A summary and pharmacological classification. Nature Reviews Drug Discovery, 7(1), 21–39.
Lewis, J. , (2014). From Flavr Savr tomatoes to stem cell therapy: Young people’s understandings of gene technology, 15 years on. Science & Education, 23(2), 361–379.
Liang, X. , Potter, J. , Kumar, S. , Ravinder, N. , & Chesnut, J. D. , (2017). Enhanced CRISPR/ Cas9-mediated precise genome editing by improved design and delivery of gRNA, Cas9 nuclease, and donor DNA. Journal of Biotechnology, 241, 136–146.
Lin, W. , Wu, X. , & Wang, Z. , (1999). A full-length cDNA of hREV3 is predicted to encode DNA polymerase ζ for damage-induced mutagenesis in humans. Mutation Research/ DNA Repair, 433(2), 89–98.
Loenen, W. A. , Dryden, D. T. , Raleigh, E. A. , Wilson, G. G. , & Murray, N. E. , (2014). Highlights of the DNA cutters: A short history of the restriction enzymes. Nucleic Acids Research, 42(1), 3–19.
Ma, A. D. , & Carrizosa, D. , (2006). Acquired factor VIII inhibitors: Pathophysiology and treatment. Hematology, 2006(1), 432–437.
Mahfouz, M. M. , Li, L. , Shamimuzzaman, M. , Wibowo, A. , Fang, X. , & Zhu, J. K. , (2011). De novo-engineered transcription activator-like effector (TALE) hybrid nuclease with novel DNA binding specificity creates double-strand breaks. Proceedings of the National Academy of Sciences, 108(6), 2623–2628.
Malyarchuk, S. , Wright, D. , Castore, R. , Klepper, E. , Weiss, B. , Doherty, A. J. , & Harrison, L. , (2007). Expression of Mycobacterium tuberculosis Ku and ligase D in Escherichia coli results in RecA and RecB-independent DNA end-joining at regions of

microhomology. DNA Repair, 6(10), 1413–1424.
Maniatis, T. , Hardison, R. C. , Lacy, E. , Lauer, J. , O'Connell, C. , Quon, D. , Sim, G. K. , & Efstratiadis, A. , (1978). The isolation of structural genes from libraries of eucaryotic DNA. Cell, 15(2), 687–701.
Mannucci, P. M. , & Franchini, M. , (2013). Present and future challenges in the treatment of haemophilia: A clinician’s perspective. Blood Transfusion, 11(Suppl 4), s77.
McComb, R. B. , Bowers, Jr. G. N. , & Posen, S. , (2013). Alkaline Phosphatase. Springer Science & Business Media.
McHughen, A. , & Smyth, S. , (2008). US regulatory system for genetically modified [genetically modified organism (GMO), RDNA or transgenic] crop cultivars. Plant Biotechnology Journal, 6(1), 2–12.
Mehra, S. , Sharma, P. , & Chadha, P. , (2020). Chapter 5; Genetically modified organisms: Applications and related ethical issues. Biotechnology Bioscience, 65.
Monk, A. , Rees, C. , Barrow, P. , Hagens, S. , & Harper, D. , (2010). Bacteriophage applications: Where are we now? Letters in Applied Microbiology, 51(4), 363–369.
Morfini, M. , Coppola, A. , Franchini, M. , & Di Minno, G. , (2013). Clinical use of factor VIII and factor IX concentrates. Blood Transfusion, 11(Suppl 4), s55.
Muntaha, S. T. , Ahmed, A. , & Ahmed, K. , (2016). Applications and future prospects of genetic engineering: A new global perspective. FUUAST Journal of Biology, 6(2), 201–209.
Murtola, M. , Wenska, M. , & Strömberg, R. , (2010). PNAzymes that are artificial RNA restriction enzymes. Journal of the American Chemical Society, 132(26), 8984–8990.
Naik, G. , Qaim, M. , Subramanian, A. , & Zilberman, D. , (2005). Bt cotton controversy: Some paradoxes explained. Economic and Political Weekly, 1514–1517.
Nair, A. S. , (2019). Pharmacogenomics of inhalational anesthetic agents. Medical Gas Research, 9(1), 52.
Namouchi, A. , & Mardassi, H. , (2006). A genomic library-based amplification approach (GL-PCR) for the mapping of multiple IS6110 insertion sites and strain differentiation of Mycobacterium tuberculosis. Journal of Microbiological Methods, 67(2), 202–211.
Oliveira, C. , Aguiar, T. Q. , & Domingues, L. , (2017). Principles of genetic engineering. In: Current Developments in Biotechnology and Bioengineering (pp. 81–127). Elsevier.
Pingoud, A. , Wilson, G. G. , & Wende, W. , (2014). Type II restriction endonucleases—A historical perspective and more. Nucleic Acids Research, 42(12), 7489–7527.
Popa, M. E. , Mitelut, A. C. , Popa, E. E. , & Matei, F. , (2019). Creating products and services in food biotechnology. In: Introduction to Biotech Entrepreneurship: From Idea to Business (pp. 141–178). Springer.
Preston, B. D. , Poiesz, B. J. , & Loeb, L. A. , (1988). Fidelity of HIV-1 reverse transcriptase. Science, 242(4882), 1168–1171.
Qaim, M. , & De Janvry, A. , (2005). Bt cotton and pesticide use in Argentina: Economic and environmental effects. Environment and Development Economics, 179–200.
Rao, D. N. , Dryden, D. T. , & Bheemanaik, S. , (2014). Type III restriction-modification enzymes: A historical perspective. Nucleic Acids Research, 42(1), 45–55.
Roberts, J. D. , Bebenek, K. , & Kunkel, T. A. , (1988). The accuracy of reverse transcriptase from HIV-1. Science, 242(4882), 1171–1173.
Roberts, R. J. , (2005). How restriction enzymes became the workhorses of molecular biology. Proceedings of the National Academy of Sciences, 102(17), 5905–5908.
Roberts, R. J. , Vincze, T. , Posfai, J. , & Macelis, D. , (2005). REBASE—Restriction enzymes and DNA methyltransferases. Nucleic Acids Research, 33(suppl_1), D230–D232.
Roberts, R. J. , Vincze, T. , Posfai, J. , & Macelis, D. , (2010). REBASE—A database for DNA restriction and modification: Enzymes, genes and genomes. Nucleic Acids Research, 38(suppl_1), D234–D236.
Sadashivappa, P. , & Qaim, M. , (2009). Bt Cotton in India: Development of Benefits and the Role of Government Seed Price Interventions. AgBioForum, 12(2) 172–183.
Sahoo, A. , Mandal, A. K. , Dwivedi, K. , & Kumar, V. , (2020). A cross-talk between the immunization and edible vaccine from natural origin: Current challenges and future prospects. Life Sciences, 118343.

Schwarz, F. W. , Tóth, J. , Van, A. K. , Cui, G. , Clausing, S. , Szczelkun, M. D. , & Seidel, R. , (2013). The helicase-like domains of type III restriction enzymes trigger long-range diffusion along DNA. Science, 340(6130), 353–356.
Shannon, A. , Le, N. T. T. , Selisko, B. , Eydoux, C. , Alvarez, K. , Guillemot, J. C. , Decroly, E. , et al. , (2020). Remdesivir and SARS-CoV-2: Structural requirements at both nsp12 RdRp and nsp14 Exonuclease active-sites. Antiviral Research, 178, 104793.
Shukla, R. , (2020). Pharmacogenomics: Overview, applications, and recent developments. Drug Design-Novel Advances in the Omics Field and Applications.
Soutar, A. , (2014). Herbert Boyer and Stanley Cohen: Recombinant DNA. Pioneers of Medicine Without a Nobel Prize, 179.
Steer, P. A. , Kirkpatrick, N. C. , O'Rourke, D. , & Noormohammadi, A. H. , (2009). Classification of fowl adenovirus serotypes by use of high-resolution melting-curve analysis of the hexon gene region. Journal of Clinical Microbiology, 47(2), 311–321.
Stewart, P. A. , & McLean, W. P. , (2005). Public opinion toward the first, second, and third generations of plant biotechnology. In Vitro Cellular & Developmental Biology-Plant, 41(6), 718–724.
Stoddard, B. L. , (2005). Homing endonuclease structure and function. Quarterly Reviews of Biophysics, 38(1), 49.
Sulakvelidze, A. , Alavidze, Z. , & Morris, J. G. , (2001). Bacteriophage therapy. Antimicrobial Agents and Chemotherapy, 45(3), 649–659.
Tahbaz, N. , Subedi, S. , & Weinfeld, M. , (2012). Role of polynucleotide kinase/phosphatase in mitochondrial DNA repair. Nucleic Acids Research, 40(8), 3484–3495.
Takeuchi, R. , Lambert, A. R. , Mak, A. N. S. , Jacoby, K. , Dickson, R. J. , Gloor, G. B. , Scharenberg, A. M. , et al., (2011). Tapping natural reservoirs of homing endonucleases for targeted gene modification. Proceedings of the National Academy of Sciences, 108(32), 13077–13082.
Tester, M. , & Langridge, P. , (2010). Breeding technologies to increase crop production in a changing world. Science, 327(5967), 818–822.
Thomas, J. J. , (2008). Innovation in India and China: Challenges and Prospects in Pharmaceuticals and Biotechnology. Citeseer.
Valdez-Cruz, N. A. , Caspeta, L. , Pérez, N. O. , Ramírez, O. T. , & Trujillo-Roldán, M. A. , (2010). Production of recombinant proteins in E. coli by the heat-inducible expression system based on the phage lambda pL and/or pR promoters. Microbial Cell Factories, 9(1), 1–16.
Van, D. S. , Molloy, P. , Varinli, H. , Morrison, J. , & Muhlhausler, B. , (2015). Epigenetics and human obesity. International Journal of Obesity, 39(1), 85–97.
Verma, I. M. , (1977). The reverse transcriptase. Biochimica et Biophysica Acta (BBA)Reviews on Cancer, 473(1), 1–38.
Verma, S. , Dutta, T. , Mahadevan, S. , Nalini, P. , Basu, D. , Biswal, N. , Ramesh, A. , et al., (2016). A randomized study of very low-dose factor VIII prophylaxis in severe haemophilia–A success story from a resource-limited country. Haemophilia, 22(3), 342–348.
Wallace, R. B. , Johnson, M. J. , Suggs, S. V. , Ken-Ichi, M. , Bhatt, R. , & Keiichi, I. , (1981). A set of synthetic oligodeoxyribonucleotide primers for DNA sequencing in the plasmid vector pBR322. Gene, 16(1–3), 21–26.
Wilson, M. H. , Coates, C. J. , & George, Jr. A. L. , (2007). PiggyBac transposon-mediated gene transfer in human cells. Molecular Therapy, 15(1), 139–145.
Wong, D. W. , (2006). Cloning vectors for introducing genes into host cells. The ABCs of Gene Cloning, 93–124.
Yamaguchi, T. , & Blumwald, E. , (2005). Developing salt-tolerant crop plants: Challenges and opportunities. Trends in Plant Science, 10(12), 615–620.
Yi, D. , (2008). Cancer, viruses, and mass migration: Paul Berg’s venture into eukaryotic biology and the advent of recombinant DNA research and technology, 1967–1980. Journal of the History of Biology, 41(4), 589–636.
Yuan, Q. , Zhang, Y. , Chen, T. , Lu, D. , Zhao, Z. , Zhang, X. , Li, Z. , et al., (2012). Photonmanipulated drug release from a mesoporous nanocontainer controlled by azobenzenemodified nucleic acid. ACS Nano, 6(7), 6337–6344.
Zachariah, S. , & Pappachen, L. , (2009). A study of genetic engineering techniques in biotechnology-based pharmaceuticals. The Internet Journal of Nanotechnology, 3(1).

Zeitlin, L. , Pettitt, J. , Scully, C. , Bohorova, N. , Kim, D. , Pauly, M. , Hiatt, A. , et al., (2011). Enhanced potency of a fucose-free monoclonal antibody being developed as an Ebola virus immunoprotectant. Proceedings of the National Academy of Sciences, 108(51), 20690–20694.

Introduction of Recombinant DNA into Host Cells

Aggarwal, D. , Kumar, A. , & Reddy, M. S. , (2011). Agrobacterium tumefaciens mediated genetic transformation of selected elite clone (s) of Eucalyptus tereticornis. Acta Physiologiae Plantarum, 33(5), 1603–1611.

Ardekani, M. R. S. , Abdin, M. Z. , Nasrullah, N. A. Z. I. M. A. , & Samim, M. , (2014). Calcium phosphate nanoparticles a novel non-viral gene delivery system for genetic transformation of tobacco. Int. J. Pharm. Pharm. Sci., 6(6), 605–609.

Binns, A. N. , & Thomashow, M. F. , (1988). Cell biology of agrobacterium infection and transformation of plants. Annual Reviews in Microbiology, 42(1), 575–606.

Bulgakov, V. P. , Kiselev, K. V. , Yakovlev, K. V. , Zhuravlev, Y. N. , Gontcharov, A. A. , & Odintsova, N. A. , (2006). Agrobacterium-mediated transformation of sea urchin embryos. Biotechnology Journal, 1(4), 454–461. doi: 10.1002/biot.200500045.

Calvin, N. M. , & Hanawalt, P. C. , (1988). High-efficiency transformation of bacterial cells by electroporation. Journal of Bacteriology, 170(6), 2796–2801. doi: 10.1128/jb.170.6.2796-2801.1988.

Celis, J. E. , (1984). Microinjection of somatic cells with micropipettes: Comparison with other transfer techniques. Biochemical Journal, 223(2), 281–291. doi: 10.1042/bj2230281.

Chu, G. , Hayakawa, H. , & Berg, P. , (1987). Electroporation for the efficient transfection of mammalian cells with DNA. Nucleic Acids Research, 15(3), 1311–1326.

Cohen, R. N. , Marieke, A. E. M. , Macaraeg, N. , Lee, A. P. , & Szoka, F. C. , (2009). Quantification of plasmid DNA copies in the nucleus after lipoplex and polyplex transfection. Journal of Controlled Release, 135(2), 166–174.

Fraley, R. , Subramani, S. , Berg, P. , & Papahadjopoulos, D. , (1980). Introduction of liposome-encapsulated SV40 DNA into cells. Journal of Biological Chemistry, 255(21), 10431–10435.

Fromm, M. E. , Taylor, L. P. , & Walbot, V. , (1986). Stable transformation of maize after gene transfer by electroporation. Nature, 319(6056), 791–793.

Gordon, J. W. , Scangos, G. A. , Plotkin, D. J. , Barbosa, J. A. , & Ruddle, F. H. , (1980). Genetic transformation of mouse embryos by microinjection of purified DNA. Proceedings of the National Academy of Sciences, 77(12), 7380–7384.

Graessmann, A. , (1968). Doctoral Dissertation. Free University of Berlin.

Graham, F. L. , & Van, D. E. A. J. , (1973). A new technique for the assay of infectivity of human adenovirus 5 DNA. Journal of Virology, 52(2), 456–467. https://doi.org/10.1016/0042-6822(73)90341-3.

Gulick, T. , (2001). Transfection using DEAE-dextran. Current Protocols in Molecular Biology. doi: 1010.1002/0471142727.mb0902s40.

Guo, Y. , Liang, H. , & Berns, M. W. , (1995). Laser-mediated gene transfer in rice. Physiologia Plantarum, 93(1), 19–24. doi: 10.1034/j.1399-3054.1995.930104.x.

Hafez, I. , Maurer, N. , & Cullis, P. , (2001). On the mechanism whereby cationic lipids promote intracellular delivery of polynucleic acids. Journal of Gene Therapy, 8, 1188–1196. https://doi.org/10.1038/sj.gt.3301506.

Ilarduya, C. T. , Sun, Y. , & Düzgüneş, N. , (2010). Gene delivery by lipoplexes and polyplexes. European Journal of Pharmaceutical Sciences, 40(3), 159–170.

Jarvis, D. L. , Weinkauf, C. , & Guarino, L. A. , (1996). Immediate-early baculovirus vectors for foreign gene expression in transformed or infected insect cells. Protein Expression and Purification, 8(2), 191–203.

Johnston, S. A. , (1990). Biolistic Transformation: Microbes to Mice. Journal of Nature, 346(6286), 776–777. doi: 10.1038/346776a0.

Kim, T. K. , & Eberwine, J. H. , (2010). Mammalian cell transfection: The present and the future. Journal of Anal. Bioanal. Chem., 397, 3173–3178. https://doi.org/10.1007/s00216-010-382-6.
Klein, T. M. , Arentzen, R. , Lewis, P. A. , & Fitzpatrick-McElligott, S. , (1992). Transformation of microbes, plants and animals by particle bombardment. Journal of Nature Biotechnology, 10(3), 286–291. doi: 10.1038/nbt0392-286.
Klein, T. M. , Goff, S. A. , Roth, B. A. , & Fromm, M. E. (1990). Applications of the Particle Gun in Plant Biology. Current Plant Science and Biotechnology in Agriculture, 56–66. doi:1010.1007/978-94-009-2103-0_8.
Kumar, P. , Nagarajan, A. , & Uchil, P. A. , (2018). DEAE-dextran transfection. Cold Spring Harbor Protocols, (7). doi: 1010.1101/pdb.top096263.
Lalani, J. , & Misra, A. , (2011). Gene delivery using chemical methods. CHALLENGES in Delivery of Therapeutic Genomics and Proteomics, 127–206. Doi:10.1016/b978-0-12-384964-9.00004-9.
Li, X. , Sui, X. , Zhang, Y. , Sun, Y. , Zhao, Y. , Zhai, Y. , & Wang, Q. , (2010). An improved calcium chloride method preparation and transformation of competent cells. African Journal of Biotechnology, 9(50), 8549–8554.
Lico, C. , Chen, Q. , & Santi, L. , (2008). Viral vectors for production of recombinant proteins in plants. Journal of Cellular Physiology, 216(2), 366–377. doi: 10.1002/jcp.21423.
Lv, H. , Zhang, S. , Wang, B. , Cui, S. , & Yan, J. , (2006). Toxicity of cationic lipids and cationic polymers in gene delivery. Journal of Controlled Release, 114(1), 100–109. doi: 10.1016/j.jconrel.2006.04.014.
Maitra, A. , (2005). Calcium phosphate nanoparticles: Second-generation nonviral vectors in gene therapy. Journal of Expert Review of Molecular Diagnostics, 5(6), 893–905. https://doi.org/10.1586/14737159.5.6.893.
Mounkes, L. C. , Zhong, W. , Cipres-Palacin, G. , Heath, T. D. , & Debs, R. J. , (1998). Proteoglycans mediate cationic liposome-DNA complex-based gene delivery in vitro and invivo. Journal of Biological Chemistry, 273(40), 26164–26170.
Neuhaus, G. , & Spangenberg, G. , (1990). Plant transformation by microinjection techniques. Physiologia Plantarum, 79(1), 213–217. doi: 10.1111/j.1399-3054.1990.tb05890.x.
Neuhaus, G. , & Spangenberg, G. , (1990). Plant transformation by microinjection techniques. Physiologia Plantarum, 79(1), 213–217.
Nomura, K. , & Komamine, A. , (1985). Identification and isolation of single cells that produce somatic embryos at a high frequency in a carrot suspension culture. Journal of Plant Physiology, 79(4), 988–991. doi: 10.1104/pp.79.4.988.
Ohashi, S. , Kubo, T. , & Ikeda, T. , (2001). Cationic polymer-mediated genetic transduction into cultured human chondro sarcoma-derived HCS-2/8 cells. Journal of Orthopaedic Science, 6, 75–81. https://doi.org/10.1007/s007760170028.
Opabode, J. T. , (2006). Agrobacterium-mediated transformation of plants: Emerging factors that influence efficiency. Biotechnology and Molecular Biology Reviews, 1(1), 12–20.
Pazzagli, M. , Devine, J. H. , Peterson, D. O. , & Baldwin, T. O. , (1992). Use of bacterial and firefly luciferases as reporter genes in DEAE-dextran-mediated transfection of mammalian cells. Analytical Biochemistry, 204(2), 315–323.
Ramsay, E. , Hadgraft, J. , Birchall, J. , & Gumbleton, M. , (2000). Examination of the biophysical interaction between plasmid DNA and the polycations, polylysine and polyornithine, as a basis for their differential gene transfection in-vitro. International Journal of Pharmaceutics, 210(1, 2), 97–107.
Roy, I. , Mitra, S. , Maitra, A. , & Mozumdar, S. , (2003). Calcium phosphate nanoparticles as novel non-viral vectors for targeted gene delivery. International Journal of Pharmaceutics, 250(1), 25–33.
Sanford, J. , (1988). The biolistic process. Trends in Biotechnology, 6(12), 299–302. doi: 10.1016/0167-7799(88)90023-6.
Schneckenburger, H. , Hendinger, A. , Sailer, R. , Strauss, W. S. L. , & Schmitt, M. , (2002). Laser-assisted optoporation of single cells. Journal of Biomedical Optics, 7(3), 410. doi: 10.1117/1.1485758.

Sharma, K. K. , Gupta, S. , & Kuhad, R. C. , (2006). Agrobacterium-mediated delivery of marker genes to Phanerochaete chrysosporium mycelial pellets: A model transformation system for white-rot fungi. Biotechnology and Applied Biochemistry, 43(3), 181–186.
Shigekawa, K. , & Dower, W. J. , (1988). Electroporation of eukaryotes and prokaryotes: A general approach to the introduction of macromolecules into cells. Journal of BioTechniques, 6(8), 742–751.
Smith, E. F. , & Townsend, C. O. , (1907). A plant-tumor of bacterial origin. Science, 25(643), 671–673.
Sparks, C. A. , Doherty, A. , & Jones, H. D. , (2014). Genetic transformation of wheat via agrobacterium-mediated DNA delivery. In: Cereal Genomics (pp. 235–250). Humana Press, Totowa, NJ.
Sussman, D. J. , & Milman, G. , (1984). Short-term, high-efficiency expression of transfected DNA. Molecular and Cellular Biology, 4(8), 1641–1643. doi: 10.1128/mcb.4.8.1641.
Vaheri, A. , & Pagano, J. S. , (1965). Infectious poliovirus RNA: A sensitive method of assay. Journal of Virology, 27(3), 434–436. doi:10.1016/0042–6822(65)90126–1.
Vile, R. G. , & Russell, S. J. , (1995). Retroviruses as vectors. British Medical Bulletin, 51(1), 12–30.
Walther, W. , & Stein, U. , (2000). Viral vectors for gene transfer. Journal of Drugs, 60(2), 249–271. https://doi.org/10.2165/00003495-200060020-00002.
Warnock, J. N. , Merten, O. W. , & Al-Rubeai, M. , (2006). Cell culture processes for the production of viral vectors for gene therapy Purposes. Journal of Cytotechnology, 50, 141–162. doi:10.1007/s10616–005–5507-z.
Williams, R. S. , Johnston, S. A. , Reidy, M. , DeVit, M. J. , McElligott, S. G. , & Sanford, J. C. , (1991). Introduction of foreign genes into tissues of living mice by DNA-coated microprojectiles. Proceedings of the National Academy of Sciences, 88(7), 2726–2730. doi: 10.1073/pnas.88.7.2726.
Yoshida, N. , & Sato, M. , (2009). Plasmid uptake by bacteria: A comparison of methods and efficiencies. Applied Microbiology and Biotechnology, 83(5), 791–798.

Linking of Desired Gene with DNA Vector/Gene Cloning Vector

Addgene . DNA Ligation. https://www.addgene.org/protocols/dna-ligation/s
Boros, I. , Pósfai, G. , & Venetianer, P. , (1984). High-copy-number derivatives of the plasmid cloning vector pBR322. Gene., 30(1–3), 257–260.
Brandt, M. E. , Gabrik, A. H. , & Vickery, L. E. , (1991). A vector for directional cloning and expression of polymerase chain reaction products in Escherichia coli. Gene., 97(1), 113–117.
Casali, N. , & Preston, A. , (2003). E. coli Plasmid Vectors: Methods and Applications (Vol. 235). Springer Science & Business Media.
Chen, Y. , Batra, H. , Dong, J. , Chen, C. , Rao, V. B. , & Tao, P. , (2019). Genetic engineering of bacteriophages against infectious diseases. Frontiers in Microbiology, 10, 954.
Cornel, M. E. W. B. , (2007). Cloning DNA fragments. In Cornel, M. E. W. B. , (ed.), Molecular Biology and Genomics (pp. 105–129). Academic Press.
Del, S. G. , Giraldo, R. , Ruiz-Echevarría, M. J. , Espinosa, M. , & Díaz-Orejas, R. , (1998). Replication and control of circular bacterial plasmids. Microbiology and Molecular Biology Reviews, 62(2), 434–464.
Griffiths, A. , Miller, J. , Suzuki, D. , Lewontin, R. , & Gelbart, W. , (2000). An Introduction to Genetic Analysis (p. 960). WH Freeman. New York.
Howe, J. G. , (2018). In: Nader, R. A. R. H. , & Carl, T. W. , (eds.), Principles of Molecular Biology. Elsevier.
Karcher, S. J. , (1995). Recombinant DNA cloning. In: Karcher, S. J. , (ed.), Molecular Biology (pp. 45–134). Academic Press.
Leonard, G. , Davis, M. D. D. , & James, F. B. , (1986). Restriction endonucleases (REs) and their use. In: Leonard, G. D. M. D. D. , & James, F. B. , (eds.), Basic Methods in Molecular

Biology (pp. 51–57). Elsevier.
Lodish, H. , & Zipursky, S. L. , (2001). Molecular cell biology. Biochem Mol Biol Educ., 29, 126–133.
Boca Scientific Inc. Standard Cloning Vector pUC19. from https://www.bocascientific.com/standard-cloning-vector-puc19-p-774.html (accessed on 12 October 2022).
Carter, M. , and Shieh, J. (2010). Molecular cloning and recombinant DNA technology. Guide to Research Techniques in Neuroscience (pp. 207–227). Academic Press.
Carter, M. , and Shieh, J. (2015). Molecular cloning and recombinant DNA technology. Guide to Research Techniques in Neuroscience (Second ed., pp. 219–237). Academic Press.
National Human Genome Research Institute . Bacterial Artificial Chromosome (Bac). https://www.genome.gov/genetics-glossary/Bacterial-Artificial-Chromosome
Orbit Biotech (2018). YACs. Molecular Biology. from https://orbitbiotech.com/yeastartificial-chromosomes-yac-yeast-artificial-chromosomes-yac-ycp-yep-murray/ (accessed on 12 October 2022).
Roberts, R. J. , Vincze, T. , Posfai, J. , & Macelis, D. , (2015). REBASE—A database for DNA restriction and modification: Enzymes, genes and genomes. Nucleic Acids Research, 43(D1), D298, D299.
She, K. , (2003). So you want to work with giants: The BAC vector. BioTech. J., 1, 69–74.
Suzuki, D. T. , & Griffiths, A. J. , (1976). An Introduction to Genetic Analysis: WH Freeman and Company.
Xavier, M. A. S. , Kipnis, A. , Torres, F. A. G. , & Astofi-Filho, S. , (2009). New vectors derives from pUC 18 for cloning and thermal-induced expression in Escherichia coli. Brazilian Journal of Microbiology. 40(4), 778–781.

Polymerase Chain Reaction

Ajmone-Marsan, P. , Negrini, R. , Milanesi, E. , Bozzi, R. , Nijman, I. J. , Buntjer, J. B. , & Lenstra, J. A. , (2002). Genetic distances within and across cattle breeds as indicated by biallelic AFLP markers. Animal Genetics, 33(4), 280–286.
Amos, W. , Goldstein, D. B. , & Schlötterer, C. , (1999). Microsatellites: Evolution and Applications.
Arnheim, N. , & Erlich, H. , (1992). Polymerase chain reaction strategy. Annual Review of Biochemistry, 61(1), 131–156.
Bagasra, O. , (2007). Protocols for the in situ PCR amplification and detection of mRNA and DNA sequences. Nature Protocols, 2(11), 2782–2795.
Ballesteros, E. , (2006). Molecular diagnostics in coagulation. In: Molecular Diagnostics (pp. 311–320). Humana Press.
Bartlett, J. M. , & Stirling, D. , (2003). PCR protocols (Vol. 226, pp. 3–525). Totowa, NJ, USA: Humana Press.
Bassler, H. A. , Flood, S. J. , Livak, K. J. , Marmaro, J. , Knorr, R. , & Batt, C. A. , (1995). Use of a fluorogenic probe in a PCR-based assay for the detection of Listeria monocytogenes. Applied and Environmental Microbiology, 61(10), 3724–3728.
Bernard, P. S. , & Wittwer, C. T. , (2002). Real-time PCR technology for cancer diagnostics. Clinical Chemistry, 48(8), 1178–1185.
Brandt, M. E. , Padhye, A. A. , Mayer, L. W. , & Holloway, B. P. , (1998). Utility of random amplified polymorphic DNA PCR and TaqMan automated detection in molecular identification of Aspergillus fumigatus. Journal of Clinical Microbiology, 36(7), 2057–2062.
Breslauer, K. J. , Frank, R. , Blöcker, H. , & Marky, L. A. , (1986). Predicting DNA duplex stability from the base sequence. Proceedings of the National Academy of Sciences, 83(11), 3746–3750.
Buntjer, J. B. , Otsen, M. , Nijman, I. J. , Kuiper, M. T. R. , & Lenstra, J. A. , (2002). Phylogeny of bovine species based on AFLP fingerprinting. Heredity, 88(1), 46–51.

Bustin, S. A. , (2000). Absolute quantification of mRNA using real-time reverse transcription polymerase chain reaction assays. Journal of Molecular Endocrinology, 25(2), 169–193.
Bustin, S. A. , Benes, V. , Nolan, T. , & Pfaffl, M. W. , (2005). Quantitative real-time RT-PCR–a perspective. Journal of Molecular Endocrinology, 34(3), 597–601.
Chamberlain, J. S. , Chamberlain, J. R. , Mullis, K. , Ferré, F. , & Gibbs, R. , (1994). The Polymerase Chain Reaction.
Chen, Q. , Lu, P. , Jones, A. V. , Cross, N. C. , Silver, R. T. , & Wang, Y. L. , (2007). Amplification refractory mutation system, a highly sensitive and simple polymerase chain reaction assay, for the detection of JAK2 V617F mutation in chronic myeloproliferative disorders. The Journal of Molecular Diagnostics, 9(2), 272–276.
Chou, Q. , Russell, M. , Birch, D. E. , Raymond, J. , & Bloch, W. , (1992). Prevention of pre-PCR mispriming and primer dimerization improves low-copy-number amplifications. Nucleic Acids Research, 20(7), 1717–1723.
Clark, A. G. , Hubisz, M. J. , Bustamante, C. D. , Williamson, S. H. , & Nielsen, R. , (2005). Ascertainment bias in studies of human genome-wide polymorphism. Genome Research, 15(11), 1496–1502.
D'Aquila, R. T. , Bechtel, L. J. , Videler, J. A. , Eron, J. J. , Gorczyca, P. , & Kaplan, J. C. , (1991). Maximizing sensitivity and specificity of PCR by pre-amplification heating. Nucleic Acids Research, 19(13), 3749.
De Marchi, M. , Dalvit, C. , Targhetta, C. , & Cassandro, M. , (2006). Assessing genetic diversity in indigenous Veneto chicken breeds using AFLP markers. Animal Genetics, 37(2), 101–105.
Dieffenbach, C. W. , Lowe, T. M. , & Dveksler, G. S. , (1993). General concepts for PCR primer design. PCR Methods Appl., 3(3), S30–S37.
Edwards, M. C. , & Gibbs, R. A. , (1994). Multiplex PCR: Advantages, development, and applications. Genome Research, 3(4), S65–S75.
Espy, M. J. , Patel, R. , Paya, C. V. , & Smith, T. F. , (2001). Quantification of Epstein-Barr virus (EBV) viral load in transplant patients by light cycler PCR. In: 101st General Meeting of the American Society for Microbiology, No. C-148. Orlando, Florida.
Ferré, F. , Marchese, A. , Pezzoli, P. , Griffin, S. , Buxton, E. , & Boyer, V. , (1994). Quantitative PCR: An overview. The Polymerase Chain Reaction, 67–88.
Freeman, W. M. , Walker, S. J. , & Vrana, K. E. , (1999). Quantitative RT-PCR: Pitfalls and potential. Biotechniques, 26(1), 112–125.
Frey, U. H. , Bachmann, H. S. , Peters, J. , & Siffert, W. , (2008). PCR-amplification of GC-rich regions: 'slowdown PCR'. Nature Protocols, 3(8), 1312–1317.
Germer, S. , & Higuchi, R. , (1999). Single-tube genotyping without oligonucleotide probes. Genome Research, 9(1), 72–78.
Gibson, U. E. , Heid, C. A. , & Williams, P. M. , (1996). A novel method for real time quantitative RT-PCR. Genome Research, 6(10), 995–1001.
Ginzinger, D. G. , (2002). Gene quantification using real-time quantitative PCR: An emerging technology hits the mainstream. Experimental Hematology, 30(6), 503–512.
Giulietti, A. , Overbergh, L. , Valckx, D. , Decallonne, B. , Bouillon, R. , & Mathieu, C. , (2001). An overview of real-time quantitative PCR: Applications to quantify cytokine gene expression. Methods, 25(4), 386–401.
Goodman, M. F. , (1995). DNA polymerase fidelity: Misinsertions and mismatched extensions. In: PCR Strategies (pp. 17–31). Academic Press.
Green, M. R. , & Sambrook, J. , (2019). Nested polymerase chain reaction (PCR). Cold Spring Harbor Protocols, 2019(2), pdb-prot095182.
Griffin, H. G. , Griffin, A. , Nolan, T. , & Bustin, S. A. , (1994). PCR Technology: Current Innovations. CRC Press.
Hill, D. A. , O'Sullivan, M. J. , Zhu, X. , Vollmer, R. T. , Humphrey, P. A. , Dehner, L. P. , & Pfeifer, J. D. , (2002). Practical application of molecular genetic testing as an aid to the surgical pathologic diagnosis of sarcomas: A prospective study. The American Journal of Surgical Pathology, 26(8), 965–977.
Holland, P. M. , Abramson, R. D. , Watson, R. , & Gelfand, D. H. , (1991). Detection of specific polymerase chain reaction product by utilizing the 5'----3'exonuclease activity of Thermus aquaticus DNA polymerase. Proceedings of the National Academy of Sciences,

88(16), 7276–7280.
Innis, M. A. , Gelfand, D. H. , & Sninsky, J. J. , (1999). PCR Applications: Protocols for Functional Genomics. Academic Press.
Innis, M. A. , Gelfand, D. H. , Sninsky, J. J. , & White, T. J. , (2012). PCR Protocols: A Guide to Methods and Applications. Academic Press.
International Chicken Polymorphism Map Consortium , (2004). A genetic variation map for chicken with 2.8 million single nucleotide polymorphisms. Nature, 432(7018), 717.
Jarne, P. , & Lagoda, P. J. , (1996). Microsatellites, from molecules to populations and back. Trends in Ecology & Evolution, 11(10), 424–429.
Kadri, K. , (2019). Polymerase chain reaction (PCR): Principle and applications. In: Synthetic Biology-New Interdisciplinary Science. IntechOpen.
Kemp, D. J. , Smith, D. B. , Foote, S. J. , Samaras, N. , & Peterson, M. G. , (1989). Colorimetric detection of specific DNA segments amplified by polymerase chain reactions. Proceedings of the National Academy of Sciences, 86(7), 2423–2427.
Komminoth, P. , Heitz, P. U. , & Long, A. A. , (1994). In situ polymerase chain reaction: General methodology and recent advances. Negotiations of the German Society for Pathology, 78, 146–152.
Kwok, P. Y. , & Chen, X. , (2003). Detection of single nucleotide polymorphisms. Current Issues in Molecular Biology, 5(2), 43–60.
Lawyer, F. C. , Stoffel, S. , Saiki, R. K. , Myambo, K. , Drummond, R. , & Gelfand, D. H. , (1989). Isolation, characterization, and expression in Escherichia coli of the DNA polymerase gene from Thermus aquaticus. Journal of Biological Chemistry, 264(11), 6427–6437.
Lay, M. J. , & Wittwer, C. T. , (1997). Real-time fluorescence genotyping of factor V Leiden during rapid-cycle PCR. Clinical Chemistry, 43(12), 2262–2267.
Lee, L. G. , Connell, C. R. , & Bloch, W. , (1993). Allelic discrimination by nick-translation PCR with fluorgenic probes. Nucleic Acids Research, 21(16), 3761–3766.
Livak, K. J. , Flood, S. J. , Marmaro, J. , Giusti, W. , & Deetz, K. , (1995). Oligonucleotides with fluorescent dyes at opposite ends provide a quenched probe system useful for detecting PCR product and nucleic acid hybridization. Genome Research, 4(6), 357–362.
Lo, Y. D. , Wong, I. H. , Zhang, J. , Tein, M. S. , Ng, M. H. , & Hjelm, N. M. , (1999). Quantitative analysis of aberrant p16 methylation using real-time quantitative methylation-specific polymerase chain reaction. Cancer Research, 59(16), 3899–3903.
Markham, A. F. , (1993). The polymerase chain reaction: A tool for molecular medicine. BMJ: British Medical Journal, 306(6875), 441.
McPherson, M. J. , Quirke, P. , & Taylor, G. R. , (1991). PCR: A Practical Approach. Oxford–New York–Tokyo: IRL Press at Oxford University Press.
Mercier, J. F. , Slater, G. W. , & Mayer, P. , (2003). Solid phase DNA amplification: A simple Monte Carlo lattice model. Biophysical Journal, 85(4), 2075–2086.
Mirasena, S. , Shimbhu, D. , Sanguansermsri, M. , & Sanguansermsri, T. , (2008). Detection of β-thalassemia mutations using a multiplex amplification refractory mutation system assay. Hemoglobin, 32(4), 403–409.
Mullis, K. B. , & Faloona, F. A. , (1987). Specific synthesis of DNA in vitro via apolymerasecatalyzed chain reaction. Methods in Enzymology, 155, 335–350.
Myakishev, M. V. , Khripin, Y. , Hu, S. , & Hamer, D. H. , (2001). High-throughput SNP genotyping by allele-specific PCR with universal energy-transfer-labeled primers. Genome Research, 11(1), 163–169.
Negrini, R. , Milanesi, E. , Bozzi, R. , Pellecchia, M. , & Ajmone-Marsan, P. , (2006). Tuscany autochthonous cattle breeds: An original genetic resource investigated by AFLP markers. Journal of Animal Breeding and Genetics, 123(1), 10–16.
Newton, C. R. , Graham, A. , Heptinstall, L. E. , Powell, S. J. , Summers, C. , Kalsheker, N. , & Markham, A. F. , (1989). Analysis of any point mutation in DNA. The amplification refractory mutation system (ARMS). Nucleic Acids Research, 17(7), 2503–2516.
Nielsen, R. , & Signorovitch, J. , (2003). Correcting for ascertainment biases when analyzing SNP data: Applications to the estimation of linkage disequilibrium. Theoretical Population Biology, 63(3), 245–255.
Nijman, I. J. , Otsen, M. , Verkaar, E. L. C. , De Ruijter, C. , Hanekamp, E. , Ochieng, J. W. , & Lenstra, J. A. , (2003). Hybridization of banteng (Bos javanicus) and zebu (Bos indicus)

revealed by mitochondrial DNA, satellite DNA, AFLP and microsatellites. Heredity, 90(1), 10–16.
Olek, A. , Oswald, J. , & Walter, J. , (1996). A modified and improved method for bisulphite based cytosine methylation analysis. Nucleic Acids Research, 24(24), 5064–5066.
Osterrieder, N. , Hübert, P. H. , Brandmüller, C. , & Kaaden, O. R. , (1994). A touchdown PCR for the differentiation of equine herpesvirus type 1 (EHV-1) field strains from the modified live vaccine strain RacH. Journal of Virological Methods, 50(1–3), 129–136.
Paun, O. , & Schönswetter, P. , (2012). Amplified fragment length polymorphism: An invaluable fingerprinting technique for genomic, transcriptomic, and epigenetic studies. In: Plant DNA Fingerprinting and Barcoding (pp. 75–87). Humana Press.
PCR Optimization: Reaction Conditions and Components , (2017). Applied Biosystems. Available from: https://www3.appliedbiosystems.com/cms/groups/mcb_marketing/documents/generaldocuments/cms_042520.pdf (accessed on 12 October 2022).
Polymerase Chain Reaction (PCR) . National Center for Biotechnology Information [Online]. Available from: http://www.ncbi.nlm.nih.gov/probe/docs/techpcr/ (accessed on 12 October 2022).
Primer Design Tips and Tools , (2015). Thermo Fisher Scientific, Inc. Available from: http://www.thermofisher.com/ca/en/home/products-and-services/product-types/primersoligosnucleotides/invitrogencustom-dna-oligos/primer-design-tools.html (accessed on 12 October 2022).
Rajeevan, M. S. , Vernon, S. D. , Taysavang, N. , & Unger, E. R. , (2001). Validation of arraybased gene expression profiles by real-time (kinetic) RT-PCR. The Journal of Molecular Diagnostics, 3(1), 26–31.
Ronaghi, M. , Karamohamed, S. , Pettersson, B. , Uhlén, M. , & Nyrén, P. , (1996). Real-time DNA sequencing using detection of pyrophosphate release. Analytical Biochemistry, 242(1), 84–89.
Roux, K. H. , (1994). Using mismatched primer-template pairs in touchdown PCR. BioTechniques, 16(5), 812–814.
Roux, K. H. , (1995). Optimization and troubleshooting in PCR. Genome Research, 4(5), S185–S194.
SanCristobal, M. , Chevalet, C. , Haley, C. S. , Joosten, R. , Rattink, A. P. , Harlizius, B. , & Cardellino, R. , (2006). Genetic diversity within and between European pig breeds using microsatellite markers. Animal Genetics, 37(3), 189–198.
Sapkota, B. R. , Ranjit, C. , Neupane, K. D. , & Macdonald, M. , (2008). Development and evaluation of a novel multiple-primer PCR amplification refractory mutation system for the rapid detection of mutations conferring rifampicin resistance in codon 425 of the rpoB gene of Mycobacterium leprae. Journal of Medical Microbiology, 57(2), 179–184.
Schmittgen, T. D. , & Livak, K. J. , (2008). Analyzing real-time PCR data by the comparative CT method. Nature Protocols, 3(6), 1101–1108.
Syvänen, A. C. , (2001). Accessing genetic variation: Genotyping single nucleotide polymorphisms. Nature Reviews Genetics, 2(12), 930–942.
Teh, L. K. , Lee, W. L. , Amir, J. , Salleh, M. Z. , & Ismail, R. , (2007). Single step PCR for detection of allelic variation of MDR1 gene (P-glycoprotein) among three ethnic groups in Malaysia. Journal of Clinical Pharmacy and Therapeutics, 32(3), 313–319.
van Huijsduijnen R. H. , Ayala, G. , & DeLamarter, J. F. , (1992). A means to reduce the complexity of oligonucleotides encoding degenerate peptides. Nucleic Acids Research, 20(4), 919.
van Pelt-Verkuil, E. , Van, B. A. , & Hays, J. P. , (2008). A brief comparison between in vivo DNA replicationand in vitro PCR amplification. Principles and Technical Aspects of PCR Amplification, 9–15.
Wages, Jr. J. M. , (2005). Polymerase chain reaction. Encyclopedia of Analytical Science, 243.
Wilhelm, J. , & Pingoud, A. , (2003). Real-time polymerase chain reaction. Chembiochem, 4(11), 1120–1128.
Zhang, X. Y. , & Ehrlich, M. , (1994). Detection and quantitation of low numbers of chromosomes containing bcl-2 oncogene translocations using semi-nested PCR.

Biotechniques, 16(3), 502–507.

Concept and Nature of Genes

Alberts, B. , Johnson, A. , Lewis, J. , Raff, M. , Roberts, K. , & Walter, P. , (2002). How genetic switches work. Molecular Biology of the Cell (4th edn.).
Alizadeh, F. , Karp, R. , Newberg, L. , & Weisser, D. , (1995). Physical mapping of chromosomes: A combinatorial problem in molecular biology. Algorithmica, 13, 52–76.
Avery, O. T. , MacLeod, C. M. , & MacCarty, M. , (1944). Studies on the chemical nature of the substance inducing transformation of pneumococcal types. Induction of transformation by a deoxyribonucleic acid fraction isolated from Pneumococcus type III. J. Exp. Med., 79, 137–159.
Banerji, J. et al. , (1981). Expression of a globin gene is enhanced by remote SV40 DNA sequences. Cell, 27, 299–308.
Banerji, J. et al. , (1983). A lymphocyte-speci®c cellular enhancer is located downstream of the joining region in immunoglobulin heavy chain genes. Cell, 33, 729–740.
Beadle, G. W. , & Tatum, E. L. , (1941). Genetic control of biochemical reactions in neurospora. Proceedings of the National Academy of Science USA, 27, 499–506.
Benzer, S. , (1955). Fine structure of a genetic region in bacteriophage. Proc. Nat. Icad. Sc., 41, 344–354.
Benzer, S. , (1957). The elementary units of heredity. In: McElroy, W. D. , & Glass, B. , (eds.), The Chemical Basis of Heredity (pp. 70–93). Baltimore: Johns Hopkins Press.
Berg, J. , Tymoczko, J. , & Stryer, L. , (2002). Biochemistry. W.H. Freeman and Company. ISBN 0–7167–4955–6.
Bibliographic Details for “Gene.” Wikipedia, the Free Encyclopedia. Page Version ID: 1022654359, Permanent link: https://en.wikipedia.org/w/index.php?title=Gene&oldid=1022654359.
Birnbaum, R. Y. , Clowney, E. J. , Agamy, O. et al. , (2012). Coding exons function as tissuespecific enhancers of nearby genes. Genome Res., 22(6), 1059–1068.
Blumenthal, T. , Evans, D. , Link, C. D. , Guffanti, A. , Lawson, D. , Thierry-Mieg, J. , ThierryMieg, D. et al. , (2002). A global analysis of Caenorhabditis elegans operons. Nature, 417, 851–885.
Boveri, T. , (1902). Uber mehrpolige mitosen als Mittel zur analyse des zellkerns. Verh. Phys-Med. Ges. Wurzb, 35, 60–90.
Brennickle, A. , Marchfelder, A. , & Binder, S. , (1999). RNA editing. FEMS Microbiol. Rev., 23, 297–316.
Bridges, C. B. , (1935). Salivary chromosome maps with a key to the banding of the chromosomes of Drosophila melanogaster. J. Hered., 26, 60–64.
Bridges, C. B. , (1938). A revised map of the salivary gland X-chromosome of Drosophila melanogaster. Journal of Heredity, 29, 11–13.
Britten, R. J. , & Kohne, D. E. , (1967). Nucleotide Sequence Repetition in DNA (Vol. 65, pp. 78–106). Carnegie Institute Washington Yearbook.
Britten, R. J. , & Kohne, D. E. , (1968a). Repeated sequences in DNA. Science, 161, 529–540.
Britten, R. J. , & Kohne, D. E. , (1968b). Repeated nucleotide sequences. Carnegie Institute Washington Yearbook, 66, 73–88.
Clean, M. P. , (1997). Prokaryotic Gene Expression. ndsu.edu.
Correns, C. , (1900). G. Mendel’s rule on the behavior of the offspring of hybrid races. Reports of the German Botanical Society, 18, 158–168.
De Vries, H. , (1900). The law of division of the bastards. Reports of the German Botanical Society, 18, 83–90.
Demerec, M. , & Hartman, P.F. , (1959). Complex loci in microorganisms. Ann. Rev. Microbiol., 13, 377–406.

Demerec, M. , (1960). Presented as Part of a Symposium on Genetics Held at Western Reserve University. The symposium was supported by National Science Foundation Grant G 9370.
Demerec, M. , (1961). The Nature of the gene. Am J Hum Genet., 13(1 Pt 2), 122–127.
Dobzhansky, T. , (1929). Genetical and cytological proof of translocations involving the third and fourth chromosome in Drosophila melanogaster. Biologisches Zentralblatt, 49, 408–419.
Dong, X. , Navratilova, P. , Fredman, D. et al. , (2010). Exonic remnants of whole-genome duplication reveal cis-regulatory function of coding exons. Nucleic Acids Res., 38(4), 1071–1085.
Douglass, J. et al. , (1984). Polyprotein gene expression: Generation of diversity of neuroendocrine peptides. Annual Review of Biochemistry, 53, 665–715.
Ghosh, A. , & Bansal, M. , (2003). “A glossary of DNA structures from A to Z”. Acta Crystallographica Section D., 59(Pt 4), 620–626.
Gillies, S. D. , (1983). A tissue-speci®c transcription enhancer elements is located in the major intron of a rearranged immunoglobulin heavy chain gene. Cell, 33, 717–772.
Glanville, E. V. , & Demerec, M. , (1960). Threonine, isoleucine, and isoleucine-valine mutants of Salmonella typhimurium. Genetics, 45, 1360–1374.
Green, M. M. , & Green, K.C. , (1949). Crossing over between alleles of the lozenge locus in Drosophila melanogaster. Proc. Natl. Acad. Sci. Usa, 35, 586–591.
Griffith, F. , (1928). Significance of pneumococcal types. Journal of Hygieny Cambridge, 27, 113–159.
Griffiths, A. J. F. , (2000). An Introduction to Genetic Analysis (7th edn.). W.H. Freeman.
Guhaniyogi, J. , & Brewer, G. , (2001). Regulation of mRNA stability in mammalian cells. Gene., 265(1–2), 11–23.
Gustafsson, A. Ê. , (1969). The life of Gregor Johan Mendel –tragic or not? Hereditas, 62, 239–258.
Hardison, R. , (2020). Fundamental Properties of Gene. Chapter 1; LiberText biology.
Helmrich, A. , Ballarino, M. , & Tora, L. , (2011). Collisions between replication and transcription complexes cause common fragile site instability at the longest human genes. Mol. Cell, 44, 966–977.
Henikoff, S. et al. , (1986). Gene within a gene: Nested Drosophila genes encode unrelated proteins on opposite DNA strands. Cell, 44, 33–42.
Hershey, A. D. , & Chase, M. , (1952). Independent functions of viral protein and nucleic acid in growth of bacteriophage. Journal of General Physiology, 36, 39–56.
Hosokawa, M. , Takeuchi, A. , Tanihata, J. , Iida, K. , Takeda, S. , & Hagiwara, M. , (2019). Loss of RNA-binding protein Sfpq causes long-gene transcriptopathy in skeletal muscle and severe muscle mass reduction with metabolic myopathy. iScience 13, 229–242.
Hozumi, N. , & Tonegawa, S. , (1976). Evidence for somatic rearrangement of immunoglobulin genes coding for variable and constant regions. Proceedings of the National Academy of Science USA, 73, 3628–3632.
Jacq, C. et al. , (1977). A pseudogene structure in 5S DNA of Xenopus laevis. Cell, 12, 109–120.
Janssens, F. A. , (1909). La théorie de la chiasmatypie, nouvelle interpretation des cinéses de maturation. Cellule, 25, 387–406.
Johannsen, W. , (1909). Elements of the exact theory of heredity. Jena: Gustav Fischer, 143–144.
Judson, H. F. , (1996). The Eighth Day of Creation: Markers of the Revolution in Biology. Expanded Edition. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York.
Leff, S. E. , Rosenfeld, M. G. , & Evans, R.M. , (1986). Complex transcriptional units: Diversity in gene expression by alternative RNA processing. Annu. Rev. Biochem., 55, 1091–1117.
Leslie, A. P. , (2008). Eukaryotic genome complexity. Nature Education, 1(1), 96.
Levinson, B. et al. , (1990). A transcribed gene in an intron of the human factor VIII gene. Genomics, 7, 1–11.
Lewin, B. , (1980a). Gene Expression, Eukaryotic Chromosomes (Vol. 2., 2nd edn.). New York: Wiley.

Lewis, E.B. , (1941). Another case of unequal crossing over in Drosophila melanogaster. Proc. Natl. Acad. Sci. Usa, 27, 31–34.
Lewis, E. B. , (1945). The relation of repeats to position effect in Drosophila melanogaster. Genetics, 30, 137–166.
Lewis, E.B. , (1951). Pseudoallelism and gene evolution. Cold Spring Harb. Symp. Quant. Biol., 16, 159–174.
Lopes, I. , Altab, G. , Raina, P. , & Magalhães, J.P. , (2021). Gene size matters: An analysis of gene length in the human genome. Front. Genet., 12, 559998.
Lyons, K.M. et al. , (1988). Many protein products from a few loci: Assignment of human salivary proline-rich proteins to speci®c loci. Genetics, 120, 255–265.
McClintock, B. , (1947). Cytogenetic studies of maize and neurospora. Carnegie Institute Washington Yearbook, 46, 146–152.
McClintock, B. , (1948). Mutable loci in maize. Carnegie Institute Washington Yearbook, 47, 155–169.
Mignone, F. , Gissi, C. , Liuni, S. , & Pesole, G. , (2002). Untranslated regions of mRNAs. Genome Biol., 3, Reviews0004.
Miller, O. L. Jr. , & Beatty, B. R. , (1969 b). Extrachromosomal nucleolar genes in amphibian oocytes. Genetics, 61, 133–143.
Morgan, T. H. et al. , (1915). The Mechanism of Mendelian Heredity. New York: Henry Holt.
Mortazavi, A. et al. , (2008). Mapping and quantifying mammalian transcriptomes by RNA-Seq. Nat. Methods, 5, 621–628.
Muller, H. J. , & Painter, T. S. , (1929). The cytological expression of changes in gene alignment produced by X-rays in Drosophila. American Naturalist, 63, 193–200.
Muller, H.J. , (1926). Gene as the basis of life. Proc. Internat. Cong. Plant Sci., 1, 897–921.
Nikovits, W. Jr. , Mar, J. H. , & Ordahl, C.P. , (1990). Muscle-specific activity of the skeletal troponin I promoter requires interaction between upstream regulatory sequences and elements contained within the first transcribed exon. Mol. Cell. Biol., 10, 3468–3482.
Oliver, P. , (1940). A reversion to wild type associated with crossing over in Drosophila melanogaster. Proc. Natl. Acad. Sci. Usa, 26, 452–454.
Painter, T. S. , (1934). A new method for the study of chromosome aberrations and the plotting of chromosome maps in Drosophila melanogaster. Genetics, 19, 175–188.
Parra, G. , Reymond, A. , Dabbousch, N. , Dermitzakis, E. T. , Castelo, R. et al. , (2006), Tandem chimerism as a means to increase protein complexity in the human genome. Genome Res., 16, 37–44.
Pearson, W. R. , & Lipman, D.J. , (1988). Proc. Nat. Acad. Sci., U.S.A., 85, 2444–2448.
Piatigorsky, J. , (2007). Gene Sharing and Evolution: The Diversity of Protein Functions. Harvard University Press, Cambridge, MA.
Pierce, B. A. , (2002). Genetics: A Conceptual Approach (1st edn.). New York: W.H. Freeman and Co.
Pipkin, M. E. , & Monticelli, S. , (2008). Genomics and the immune system. Immunology, 124, 23–32.
Portin, P. , & Adam, W. , (2017). The evolving definition of term “gene”. Genetics Perspectives, 205, 1353–1364.
Portin, P. , (1993). The concept of the gene: Short history and present status. Quarterly Review of Biology, 68(2), 173–223.
Portin, P. , (2002). Historical development of the concept of the gene. Journal of Medicine and Philosophy, 27(3), 257–286.
Rieger, R. et al. , (1991). Glossary of Genetics: Classical and Molecular (5th edn.). Berlin and Heidelberg: Springer-Verlag.
Salgado, H. , Moreno-Hagelsieb, G. , Smith, T. , & Collado-Vides, J. , (2000). Operons in Escherichia coli: Genomic analyses and predictions. Proceedings of the National Academy of Sciences, 97(12), 6652–6657.
Sanger, W. , (1984). Principles of Nucleic Acid Structure. New York: Springer-Verlag. ISBN 0–387–90762–9.
Sarin, C. , (2001). Genetics. Tata McGraw- Hill. ISBN 0–07–460333–7.

Schibler, U. , & Sierra, F. , (1987). Alternative promoters in developmental gene expression. Annu. Rev. Genet., 21, 237–257.

Smemo, S. , Tena, J. J. , Kim, K. H. , Gamazon, E. R. , Sakabe, N. J. , Gómez-Marín, C. et al. , (2014). Obesity-associated variants within FTO form long-range functional connections with IRX3. Nature, 507, 371–375.

Sturtevant, A.H. , (1913). The linear arrangement of the six sex-linked factors in Drosophila, as shown by their mode of association. J. Exp. Zool., 14, 43–59.

Suman, M. , (2001). Genes: Definition and Structure. USA encyclopedia of life sciences; Nature Publishing Group; www.els.net 1 (accessed on 12 October 2022).

Sutton, W.S. , (1903). The chromosomes in heredity. Biol. Bull., 4, 231–251.

Takeuchi, A. , Iida, K. , Tsubota, T. , Hosokawa, M. , Denawa, M. , Brown, J. B. et al. , (2018). Loss of Sfpq causes long-gene transcriptopathy in the brain. Cell Rep., 23, 1326–1341.

Tropp, B. E. , (2012). Molecular Biology (4th edn.). Sudbury, Mass.: Jones and Barlett Learning. ISBN 978–0–7637–8663–2.

Tschermak, E. , (1900). Ueber Ku È nstliche kreuzung bei Pisum sativum. Berichte der Deutchen Botanischen Gesellschaft, 18, 232–239.

Urrutia, A. O. , & Hurst, L. D. , (2003). The signature of selection mediated by expression on human genes. Genome Res., 13, 2260–2264.

Vassylyev, D. G. , Sekine, S. , Laptenko, O. , Lee, J. , Vassylyeva, M. N. , Borukhov, S. , & Yokoyama, S. , (2002). Crystal structure of a bacterial RNA polymerase holoenzyme at 2.6 A resolution Nature, 417, 712–719.

Waring, M. , & Britten, R.J. , (1966). Nucleotide sequence repetition: A rapidly reassociating fraction of mouse DNA. Science, 154, 791–794.

Watson, J. D. , & Crick, F. H. C. , (1953). A structure for deoxyribonucleic acid. Nature, 171, 737–738.

Weinberg, E.S. et al. , (1972). Genes coding for polysomal 9S RNA of sea urchins: Conservation and divergence. Nature, 240, 225–228.

Yanofsky, C. et al. , (1964). On the colinearity of gene structure and protein structure. Proceedings of the National Academy of Science USA, 51, 266–272.

Blotting Techniques

Alwine, J. C. , Kemp, D. J. , & Stark, G. R. , (1977). Method for detection of specific RNAs in agarose gels by transfer to diazobenzyloxymethyl-paper and hybridization with DNA probes. Proceedings of the National Academy of Sciences, 74(12), 5350–5354.

Alwine, J. C. , Kemp, D. J. , Parker, B. A. , Reiser, J. , Renart, J. , Stark, G. R. , & Wahl, G. M. , (1979). [15] Detection of specific RNAs or specific fragments of DNA by fractionation in gels and transfer to diazobenzyloxymethyl paper. In: Methods in Enzymology (Vol. 68, pp. 220–242). Academic Press.

Aviv, H. , & Leder, P. , (1972). Purification of biologically active globin messenger RNA by chromatography on oligothymidylic acid-cellulose. Proceedings of the National Academy of Sciences, 69(6), 1408–1412.

Bischoff, K. M. , Shi, L. , & Kennelly, P. J. , (1998). The detection of enzyme activity following sodium dodecyl sulfate-polyacrylamide gel electrophoresis. Analytical Biochemistry, 260(1), 1–17.

Bittner, M. , Kupferer, P. , & Morris, C. F. , (1980). Electrophoretic transfer of proteins and nucleic acids from slab gels to diazobenzylozymethyl cellulose or nitrocellulose sheets. Analytical Biochemistry, 102(2), 459–471.

Bolt, M. W. , & Mahoney, P. A. , (1997). High-efficiency blotting of proteins of diverse sizes following sodium dodecyl sulfate-polyacrylamide gel electrophoresis. Analytical Biochemistry, 247(2), 185–192.

Brown, T. A. , (2001). Southern blotting and related DNA detection techniques. eLS.

Brown, T. , (1993). Southern blotting. Current Protocols in Molecular Biology, 21(1), 2–9.
Chen, H. , & Chang, G. D. , (2001). Simultaneous immunoblotting analysis with activity gel electrophoresis in a single polyacrylamide gel. Electrophoresis, 22(10), 1894–1899.
Chen, J. Q. , Heldman, M. R. , Herrmann, M. A. , Kedei, N. , Woo, W. , Blumberg, P. M. , & Goldsmith, P. K. , (2013). Absolute quantitation of endogenous proteins with precision and accuracy using a capillary Western system. Analytical Biochemistry, 442(1), 97–103.
Chen, X. , Kapil, M. A. , Hughes, A. J. , & Herr, A. E. , (2011). Single-microchannel, multistep assay reports protein size and immunoaffinity. Analytical Chemistry, 83(17), 6573–6579.
Chomczynski, P. , & Mackey, K. , (1994). One-hour downward capillary blotting of RNA at neutral pH. Analytical Biochemistry, 221(2), 303–305.
Chomczynski, P. , & Sacchi, N. , (1987). Single-step method of RNA isolation by acid guanidinium thiocyanate-phenol-chloroform extraction. Analytical Biochemistry, 162(1), 156–159.
Chung, M. , Kim, D. , & Herr, A. E. , (2013). Microchamber Western blotting using polyL-lysine conjugated polyacrylamide gel for blotting of sodium dodecyl sulfate coated proteins. Analytical Chemistry, 85(16), 7753–7761.
De Keyser, F. , Verbruggen, G. , Veys, E. M. , Nimmegeers, J. , Schatteman, L. , Goethals, K. , & Vandenbossche, M. , (1990). “Microgel diffusion blotting” for sensitive detection of antibodies to extractable nuclear antigens. Clinical Chemistry, 36(2), 337–339.
Duncombe, T. A. , & Herr, A. E. , (2013). Photopatterned free-standing polyacrylamide gels for microfluidic protein electrophoresis. Lab on a Chip, 13(11), 2115–2123.
Elkon, K. B. , Jankowski, P. W. , & Chu, J. L. , (1984). Blotting intact immunoglobulins and other high-molecular-weight proteins after composite agarose-polyacrylamide gel electrophoresis. Analytical Biochemistry, 140(1), 208–213.
Gershoni, J. M. , & Palade, G. E. , (1982). Electrophoretic transfer of proteins from sodium dodecyl sulfate-polyacrylamide gels to a positively charged membrane filter. Analytical Biochemistry, 124(2), 396–405.
Gershoni, J. M. , & Palade, G. E. , (1983). Protein blotting: Principles and applications. Analytical Biochemistry, 131(1), 1–15.
Gershoni, J.M. , (1988). Protein blotting: A manual. Methods of Biochemical Analysis, 33, 1–58.
Gerver, R. E. , & Herr, A. E. , (2014). Microfluidic western blotting of low-molecular-mass proteins. Analytical Chemistry, 86(21), 10625–10632.
Gibson, W. , (1981). Protease-facilitated transfer of high-molecular-weight proteins during electrotransfer to nitrocellulose. Analytical Biochemistry, 118(1), 1–3.
Gravel, P. , (2008). Protein blotting. In: Molecular Biomethods Handbook (pp. 365–375). Humana Press.
Green, M. R. , & Sambrook, J. , (2021). Southern blotting. Cold Spring Harbor Protocols, 2021(7), pdb-prot100487.
Harlow, E. D. , & Lane, D. , (1988). A Laboratory Manual (p. 579). New York: Cold Spring Harbor Laboratory.
Hayes, P. C. , Wolf, C. R. , & Hayes, J. D. , (1989). Blotting techniques for the study of DNA, RNA, and proteins. BMJ: British Medical Journal, 299(6705), 965.
He, M. , & Herr, A. E. , (2009). Microfluidic polyacrylamide gel electrophoresis with in situ immunoblotting for native protein analysis. Analytical Chemistry, 81(19), 8177–8184.
He, M. , & Herr, A. E. , (2010). Automated microfluidic protein immunoblotting. Nature Protocols, 5(11), 1844–1856.
He, M. , & Herr, A. E. , (2010). Polyacrylamide gel photopatterning enables automated protein immunoblotting in a two-dimensional microdevice. Journal of the American Chemical Society, 132(8), 2512–2513.
He, M. , Novak, J. , Julian, B. A. , & Herr, A. E. , (2011). Membrane-assisted online renaturation for automated microfluidic lectin blotting. Journal of the American Chemical Society, 133(49), 19610–19613.
Herr, A. E. , (2013). Disruptive by design: A perspective on engineering in analytical chemistry. Analytical Chemistry, 85(16), 7622–7628.
Heukeshoven, J. , & Dernick, R. , (1995). Effective blotting of ultrathin polyacrylamide gels anchored to a solid matrix. Electrophoresis, 16(1), 748–756.

Hughes, A. J. , & Herr, A. E. , (2012). Microfluidic western blotting. Proceedings of the National Academy of Sciences, 109(52), 21450–21455.

Hughes, A. J. , Lin, R. K. , Peehl, D. M. , & Herr, A. E. , (2012). Microfluidic integration for automated targeted proteomic assays. Proceedings of the National Academy of Sciences, 109(16), 5972–5977.

Jägersten, C. , Edström, A. , Olsson, B. , & Jacobson, G. , (1988). Blotting from PhastGel media after horizontal sodium dodecyl sulfate-polyacrylamide gel electrophoresis. Electrophoresis, 9(10), 662–665.

Josefsen, K. , & Nielsen, H. , (2011). Northern blotting analysis. In: Rna (pp. 87–105). Humana Press.

Kang, C. C. , Lin, J. M. G. , Xu, Z. , Kumar, S. , & Herr, A. E. , (2014). Single-cell western blotting after whole-cell imaging to assess cancer chemotherapeutic response. Analytical Chemistry, 86(20), 10429–10436.

Kim, D. , Karns, K. , Tia, S. Q. , He, M. , & Herr, A. E. , (2012). Electrostatic protein immobilization using charged polyacrylamide gels and cationic detergent microfluidic western blotting. Analytical Chemistry, 84(5), 2533–2540.

Kost, J. , Liu, L. S. , Ferreira, J. , & Langer, R. , (1994). Enhanced protein blotting from PhastGel media to membranes by irradiation of low-intensity ultrasound. Analytical Biochemistry, 216(1), 27–32.

Kurien, B. T. , & Scofield, R. H. , (1997). Multiple immunoblots after non-electrophoretic bidirectional transfer of a single SDS–PAGE gel with multiple antigens. Journal of Immunological Methods, 205(1), 91–94.

Kurien, B. T. , & Scofield, R. H. , (2002). Heat-mediated, ultra-rapid electrophoretic transfer of high and low molecular weight proteins to nitrocellulose membranes. Journal of Immunological Methods, 266(1, 2), 127–133.

Kurien, B. T. , & Scofield, R. H. , (2006). Western blotting. Methods, 38(4), 283–293.

Laemmli, U. K. , (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature, 227(5259), 680–685.

Lehrach, H. , Diamond, D. , Wozney, J. M. , & Boedtker, H. , (1977). RNA molecular weight determinations by gel electrophoresis under denaturing conditions, a critical reexamination. Biochemistry, 16(21), 4743–4751.

McMaster, G. K. , & Carmichael, G. G. , (1977). Analysis of single-and double-stranded nucleic acids on polyacrylamide and agarose gels by using glyoxal and acridine orange. Proceedings of the National Academy of Sciences, 74(11), 4835–4838.

Olsen, I. , & Wiker, H. G. , (1998). Diffusion blotting for rapid production of multiple identical imprints from sodium dodecyl sulfate-polyacrylamide gel electrophoresis on a solid support. Journal of Immunological Methods, 220(1, 2), 77–84.

Patabadige, D. E. , Jia, S. , Sibbitts, J. , Sadeghi, J. , Sellens, K. , & Culbertson, C. T. , (2016). Micro total analysis systems: Fundamental advances and applications. Analytical Chemistry, 88(1), 320–338.

Peferoen, M. , Huybrechts, R. , & De Loof, A. , (1982). Vacuum-blotting: A new simple and efficient transfer of proteins from sodium dodecyl sulfate—Polyacrylamide gels to nitrocellulose. FEBS Letters, 145(2), 369–372.

Reijnders, L. , Sloof, P. , Sival, J. , & Borst, P. , (1973). Gel electrophoresis of RNA under denaturing conditions. Biochimica et Biophysica Acta (BBA)-Nucleic Acids and Protein Synthesis, 324(3), 320–333.

Reinhart, M. P. , & Malamud, D. , (1982). Protein transfer from isoelectric focusing gels: The native blot. Analytical Biochemistry, 123(2), 229–235.

Renart, J. , Reiser, J. , & Stark, G. R. , (1979). Transfer of proteins from gels to diazobenzyloxymethyl-paper and detection with antisera: A method for studying antibody specificity and antigen structure. Proceedings of the National Academy of Sciences, 76(7), 3116–3120.

Ríos, Á. , Zougagh, M. , & Avila, M. , (2012). Miniaturization through lab-on-a-chip: Utopia or reality for routine laboratories? A review. Analytica Chimica Acta, 740, 1–11.

Sanders, B. J. , Kim, D. C. , & Dunn, R. C. , (2016). Recent advances in microscale western blotting. Analytical Methods, 8(39), 7002–7013.

Southern, E. M. , (1975). Detection of specific sequences among DNA fragments separated by gel electrophoresis. J. Mol. Biol., 98(3), 503–517.
Southern, E. , (2006). Southern blotting. Nature Protocols, 1(2), 518–525.
Staehelin, T. , & Gordon, J. , (1979). Electrophoretic transfer of proteins from polyacrylamide gels to nitrocellulose sheets: Procedure and some applications. Proc. Natl. Acad. Sci. Usa, 76, 4350–4354.
Suzuki, Y. , Takeda, Y. , & Ikuta, T. , (2008). Immunoblotting conditions for human hemoglobin chains. Analytical Biochemistry, 378(2), 218–220.
Tanaka, H. , Putalun, W. , & Shoyama, Y. , (2012). Fingerprinting of natural product by eastern blotting using monoclonal antibodies. Chromatography Research International, 2012.
Tentori, A. M. , Hughes, A. J. , & Herr, A. E. , (2013). Microchamber integration unifies distinct separation modes for two-dimensional electrophoresis. Analytical Chemistry, 85(9), 4538–4545.
Tia, S. Q. , He, M. , Kim, D. , & Herr, A. E. , (2011). Multianalyte on-chip native western blotting. Analytical Chemistry, 83(9), 3581–3588.
Towbin, H. , Staehelin, T. , & Gordon, J. , (1979). Electrophoretic transfer of proteins from polyacrylamide gels to nitrocellulose sheets: Procedure and some applications. Proceedings of the National Academy of Sciences, 76(9), 4350–4354.

Chromosome Jumping

Collins, F. S. , Drumm, M. L. , Cole, J. L. , Lockwood, W. K. , Vande, W. G. F. , & Iannuzzi, M. C. , (1987). Construction of a general human chromosome jumping library, with application to cystic fibrosis. Science, 235(4792), 1046–1049.
Drumm, M. L. , (2001). Construction of chromosome jumping and linking libraries in E. coli. Current Protocols in Human Genetics, 1(1), 5.4.1–5.4.17.
Leslie, A. P. , (2008). Transposons: The jumping genes. Transposons: The jumping genes. Nature Education, 1(1), 204.
Madireddy, A. , & Gerhardt, J. , (2017). Replication through repetitive DNA elements and their role in human diseases. Advances in Experimental Medicine and Biology, 1042, 549–581.
Poustka, A. , & Lehrach, H. , (1986). Jumping libraries and linking libraries: The next generation of molecular tools in mammalian genetics. Trends in Genetics, 2, 174–179.
Poustka, A. , Pohl, T. M. , Barlow, D. P. , Frischauf, A. M. , & Lehrach, H. , (1987). Construction and use of human chromosome jumping libraries from NotI-digested DNA. Nature, 325(6102), 353–355.
Pray, L. , & Zhaurova, K. , (2008). Barbara McClintock and the discovery of jumping genes (transposons). Nature Education, 1(1), 169.
Sandeep, R. , (2012). Barbara McClintock and the discovery of jumping genes. Proceeding of the National Academy of Science in USA, 109(50), 20198, 20199.
Slade, I. , Stephens, P. , Douglas, J. , Barker, K. , Stebbings, L. , Abbaszadeh, F. , PritchardJones, K. et al. , (2009). Constitutional translocation breakpoint mapping by genomewide paired-end sequencing identifies HACE1 as a putative Wilms tumor susceptibility gene. Journal of Medical Genetics, 47(5), 342–347.
Slotkin, R. K. , & Martienssen, R. , (2007). Transposable elements and the epigenetic regulation of the genome. Nature Reviews Genetics, 8, 272–285.
Talkowski, M. E. , Ernst, C. , Heilbut, A. , Chiang, C. , Hanscom, C. , Lindgren, A. , Kirby, A. et al. , (2011). Next generation sequencing strategies enabling routine detection of balance chromosome rearrangement for clinical diagnosis and genetic research. American Journal of Human Genetics, 88(4), 469–481.

Electrophoresis

Almdal, K. , Dyre, J. , Hvidt, S. , & Kramer, O. , (1993). Towards a phenomenological definition of the term ‘gel’. Polymer Gels and Networks, 1(1), 5–17.
Barasinski, M. , & Garnweitner, G. , (2020). Restricted and unrestricted migration mechanisms of silica nanoparticles in agarose gels and their utilization for the separation of binary mixtures. J. Phys. Chem. C., 124, 5157–5166.
Bengtsson, K. , Nilsson, S. , & Robinson, N. D. , (2014). Conducting polymer electrodes for gel electrophoresis. PLoS ONE, 9(2), e89416.
Boyer, R. F. , (2000). Modern Experimental Biochemistry (3rd edn.). US: Pearson.
Brody, J. R. , & Kern, S. E. , (2004). History and principles of conductive media for standard DNA electrophoresis. Anal. Biochem., 333(1), 1–13.
Dukhin, A. S. , & Goetz, P. J. , (2017). Characterization of Liquids, Nano- and Micro-Particulates and Porous Bodies Using Ultrasound. Elsevier.
Erlandsson, P. G. , & Robinson, N. D. , (2011). Electrolysis-reducing electrodes for electrokinetic devices. Electrophoresis, 32, 784–790.
Fischer, S. G. , & Lerman, L. S. , (1979). Length-independent separation of DNA restriction fragments in two-dimensional gel electrophoresis. Cell, 16(1), 191–200.
Gordon, A. H. , (1975). Electrophoresis of Proteins in Polyacrylamide and Starch Gels. New York: American Elsevier Publishing Company, Inc.
Hofmann, A. , & Clokie, S. , (2018). Wilson and Walker’s Principles and Techniques of Biochemistry and Molecular Biology. Great Britain: Cambridge University Press.
Khademhosseini, A. , & Demirci, U. , (2016). Gels Handbook: Fundamentals, Properties and Applications. World Scientific Pub Co Inc.
Khan, M. F. , (2013). Online measurement of mass density and viscosity of pL fluid samples with suspended microchannel resonator. Sens. Actuators, B, 185, 456–461.
Lodish, H. , Berk, A. , & Matsudaira, P. , (2004). Molecular Cell Biology (5th edn.). WH Freeman: New York, NY.
Lyklema, J. , (1995). Fundamentals of Interface and Colloid Science, 2, 3, 208.
Minde, D. P. , (2012). Determining biophysical protein stability in lysates by a fast proteolysis assay. PLOS One, 7(10), e46147.
Ninfa, A. J. , Ballou, D. P. , & Benore, M. , (2009). Fundamental Laboratory Approaches for Biochemistry and Biotechnology (p. 161). Hoboken, NJ: Wiley.
Perrett, D. , (2007). From ‘protein’ to the beginnings of clinical proteomics. Proteomics: Clinical Applications, 1(8), 720–738.
Petrov, A. , Tsa, A. , & Puglisi, J. D. , (2013). Chapter 16 – Analysis of RNA by analytical polyacrylamide gel electrophoresis. In: Lorsch, J. , (ed.), Methods in Enzymology (Vol. 530, pp. 301–313). Academic Press.
Roth, C. M. , (2005). Electrophoresis nucleic acids. Encyclopedia of Analytical Science, 456–460.
Schägger, H. , (2006). Tricine–SDS-page. Nature Protocols, 1(1), 16–22.
Schulze, P. , Link, M. , Schulze, M. , Thuermann, S. , Wolfbeis, O. S. , & Belder, D. , (2010). A new weakly basic amino-reactive fluorescent label for use in isoelectric focusing and chip electrophoresis. Electrophoresis, 31, 2749–2753.
Swathi-Chaudhari, Kamalesh-Chaudhari , Seokbeom-Kim , Faheem-Khan , Jungchul-Lee , & Thomas-Thundat . (2017). Electrophoresis assisted time-of-flow mass spectrometry using hollow nanomechanical resonators. Scientific Report, 7, 3535.
Tiselius, A. , (1937). A new apparatus for electrophoretic analysis of colloidal mixtures. Transactions of the Faraday Society, 33, 524–531.
Wittig, I. , & Schägger, H. , (2005). Advantages and limitations of clear native polyacrylamide gel electrophoresis. Proteomics, 5, 4338–4346.
Wraxall, B. G. D. , & Culliford, B. J. , (1968). A thin-layer starch gel method for enzyme typing of bloodstains. J. Forensic Sci. Soc., 8(2), 81, 82.

Zilberstein, G. , Korol, L. , Antonioli, P. , Righetti, P. G. , & Bukshpan, S. , (2007). SDS-PAGE under focusing conditions: An electrokinetic transport phenomenon based on charge neutralization. Anal. Chem., 79, 821–827.

Genetically Engineered Microorganisms

Ahankoub, M. , Mardani, G. , Ghasemi-Dehkordi, P. , Mehri-Ghahfarrokhi, A. , Doosti, A. , Jami, M. S. , Allahbakhshian-Farsani, M. , et al. , (2020). Biodecomposition of phenanthrene and pyrene by a genetically engineered Escherichia coli. Recent Patents on Biotechnology, 14(2), 121-133. https://doi.org/10.2174/1872208314666200128103513.

Álvarez, B. , & Fernández, L. Á. , (2017). Sustainable therapies by engineered bacteria. Microbial Biotechnology, 10(5), 1057-1061. https://doi.org/10.1111/1751-7915.12778.

Appukuttan, D. , Rao, A. S. , & Apte, S. K. , (2006). Engineering of Deinococcus radiodurans R1 for bioprecipitation of uranium from dilute nuclear waste. Applied and Environmental Microbiology, 72(12), 7873-7878. https://doi.org/10.1128/AEM.01362-06.

Batt, C. A. , (2014). Genetic engineering. In: Encyclopedia of Food Microbiology (2nd edn., pp. 83-87). Elsevier Inc. https://doi.org/10.1016/B978-0-12-384730-0.00143-9.

Benson, J. J. , Sakkos, J. K. , Radian, A. , Wackett, L. P. , & Aksan, A. , (2018). Enhanced biodegradation of atrazine by bacteria encapsulated in organically modified silica gels. Journal of Colloid and Interface Science, 510, 57-68. https://doi.org/10.1016/jjcis.2017.09.044.

Bilal, M. , Asgher, M. , Parra-Saldivar, R. , Hu, H. , Wang, W. , Zhang, X. , & Iqbal, H. M. N. , (2017). Immobilized ligninolytic enzymes: An innovative and environmentally responsive technology to tackle dye-based industrial pollutants: A review. In: Science of the Total Environment (Vol. 576, pp. 646-659). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2016.10.137.

Bird, A. W. , Erler, A. , Fu, J. , Hériché, J. K. , Maresca, M. , Zhang, Y. , Hyman, A. A. , & Stewart, F. , (2012). High-efficiency counterselection recombineering for site-directed mutagenesis in bacterial artificial chromosomes. Articles Nature Methods, 9(1), 103. https://doi.org/10.1038/nMeth.1803.

Bongers, R. S. , Hoefnagel, M. H. N. , & Kleerebezem, M. , (2005). High-level acetaldehyde production in Lactococcus lactis by metabolic engineering. Applied and Environmental Microbiology, 71(2), 1109-1113. https://doi.org/10.1128/AEM.71.2.1109-1113.2005.

Brim, H. , McFarlan, S. C. , Fredrickson, J. K. , Minton, K. W. , Zhai, M. , Wackett, L. P. , & Daly, M. J. , (2000). Engineering Deinococcus radiodurans for metal remediation in radioactive mixed waste environments. Nature Biotechnology, 18(1), 85-90. https://doi.org/10.1038/71986.

Brim, H. , Osborne, J. P. , Kostandarithes, H. M. , Fredrickson, J. K. , Wackett, L. P. , & Daly, M. J. , (2006). Deinococcus radiodurans engineered for complete toluene degradation facilitates Cr(VI) reduction. Microbiology, 152(8), 2469-2477. https://doi.org/10.1099/mic.0.29009-0.

Burgard, A. P. , Pharkya, P. , & Maranas, C. D. , (2003). OptKnock: A bilevel programming framework for identifying gene knockout strategies for microbial strain optimization. Biotechnology and Bioengineering, 84(6), 647-657. https://doi.org/10.1002/bit.10803.

Cao, J. , Sanganyado, E. , Liu, W. , Zhang, W. , & Liu, Y. , (2019). Decolorization and detoxification of direct blue 2B by indigenous bacterial consortium. Journal of Environmental Management, 242, 229-237. https://doi.org/10.1016/j.jenvman.2019.04.067.

Cao, L. , Wang, Q. , Zhang, J. , Li, C. , Yan, X. , Lou, X. , Xia, Y. , Hong, Q. , & Li, S. , (2012). Construction of a stable genetically engineered rhamnolipid-producing microorganism for remediation of pyrene-contaminated soil. World Journal of Microbiology and Biotechnology, 28(9), 2783-2790. https://doi.org/10.1007/s11274-012-1088-0.

Chang, J. S. , & Lin, C. Y. , (2001). Decolorization kinetics of a recombinant Escherichia coli strain harboring azo-dye-decolorizing determinants from Rhodococcus sp. Biotechnology Letters, 23(8), 631-636. https://doi.org/10.1023/A:1010306114286.

Chaves, A. C. S. D. , Fernandez, M. , Lerayer, A. L. S. , Mierau, I. , Kleerebezem, M. , & Hugenholtz, J. , (2002). Metabolic engineering of acetaldehyde production by Streptococcus thermophilus. Applied and Environmental Microbiology, 68(11), 5656-5662. https://doi.org/10.1128/AEM.68.11.5656-5662.2002.
Chen, D. , Wang, H. , & Yang, K. , (2016). Effective biodegradation of nitrate, Cr(VI) and p-fluoronitrobenzene by a novel three dimensional bioelectrochemical system. Bioresource Technology, 203, 370-373. https://doi.org/10.1016/j.biortech.2015.12.059.
Chen, J. , Sun, G. X. , Wang, X. X. , Lorenzo, V. De ., Rosen, B. P. , & Zhu, Y. G. , (2014). Volatilization of arsenic from polluted soil by Pseudomonas putida engineered for expression of the arsM arsenic(III) S-adenosine methyltransferase gene. Environmental Science and Technology, 48(17), 10337-10344. https://doi.org/10.1021/es502230b.
Chen, T. , Tian, P. , Huang, Z. , Zhao, X. , Wang, H. , Xia, C. , Wang, L. , & Wei, H. , (2018). Engineered commensal bacteria prevent systemic inflammation-induced memory impairment and amyloidogenesis via producing GLP-1. Applied Microbiology and Biotechnology, 102(17), 7565-7575. https://doi.org/10.1007/s00253-018-9155-6.
Choi, K. H. , & Kim, J. , (2009). Applications of transposon-based gene delivery system in bacteria. J. Microbiol. Biotechnol, 19(3), 217-228. https://doi.org/10.4014/jmb.0811.669.
Chowdhury, A. , Zomorrodi, A. R. , & Maranas, C. D. , (2014). k-OptForce: Integrating kinetics with flux balance analysis for strain design. PLoS Computational Biology, 10(2). https://doi.org/10.1371/journal.pcbi.1003487.
Daeffler, K. N. , Galley, J. D. , Sheth, R. U. , Ortiz-Velez, L. C. , Bibb, C. O. , Shroyer, N. F. , Britton, R. A. , & Tabor, J. J. , (2017). Engineering bacterial thiosulfate and tetrathionate sensors for detecting gut inflammation. Molecular Systems Biology, 13(4), 923. https://doi.org/10.15252/msb.20167416.
Das, N. , & Chandran, P. , (2011). Research Biotechnology Research International, 2011, 13. https://doi.org/10.4061/2011/941810.
Davis, T. O. , Henderson, I. , Brehm, J. K. , & Minton, N. P. , (2000). Development of a transformation and gene reporter system for group II, non-proteolytic clostridium botulinum type B strains fermentation symposium JMMB research article. In: J. Mol. Microbiol. Biotechnol (Vol. 2, Issue 1). www.caister.com/bacteria-plant (accessed on 12 October 2022).
Davison, J. , (1999). Genetic exchange between bacteria in the environment. In: Plasmid (Vol. 42, No. 2, pp. 73-91). https://doi.org/10.1006/plas.1999.1421.
De Boeck, R. , Sarmiento-Rubiano, L. A. , Nadal, I. , Monedero, V. , Pérez-Martínez, G. , & Yebra, M. J. , (2010). Sorbitol production from lactose by engineered Lactobacillus casei deficient in sorbitol transport system and mannitol-1-phosphate dehydrogenase. Applied Microbiology and Biotechnology, 85(6), 1915-1922. https://doi.org/10.1007/s00253-009-2260-9.
Dixit, S. , & Garg, S. , (2019). Development of an efficient recombinant bacterium and its application in the degradation of environmentally hazardous azo dyes. International Journal of Environmental Science and Technology, 16(11), 7137-7146. https://doi.org/10.1007/s13762-018-2054-7.
Duan, X. Q. , Zheng, J. W. , Zhang, J. , Hang, B. J. , He, J. , & Li, S. P. , (2011). Characteristics of a 3-phenoxybenzoic acid degrading-dacterium and the construction of a engineering bacterium. Huanjing Kexue/Environmental Science, 32(1), 240-246. https://europepmc.org/article/med/21404693 (accessed on 12 October 2022).
Fasaei, N. , (2017). Site-directed mutagenesis in Brucella abortus S19 by overlap extension PCR-based procedure. Journal of the Hellenic Veterinary Medical Society, 68(3), 273-278. https://doi.org/10.12681/jhvms.15468.
Fisher, A. K. , Freedman, B. G. , Bevan, D. R. , & Senger, R. S. , (2014). A review of metabolic and enzymatic engineering strategies for designing and optimizing performance of microbial cell factories. In: Computational and Structural Biotechnology Journal (Vol. 11, No. 18, pp. 91-99). https://doi.org/10.1016/j.csbj.2014.08.010.
Fulekar, M. H. , Singh, A. , & Bhaduri, A. M. , (2009). Genetic engineering strategies for enhancing phytoremediation of heavy metals. African Journal of Biotechnology, 8(4), 529-535. http://www.academicjournals.org/AJB (accessed on 12 October 2022).
Gallo, G. , Lo Piccolo, L. , Renzone, G. , La Rosa, R. , Scaloni, A. , Quatrini, P. , & Puglia, A. M. , (2012). Differential proteomic analysis of an engineered Streptomyces coelicolor strain

reveals metabolic pathways supporting growth on n-hexadecane. Applied Microbiology and Biotechnology, 94(5), 1289-1301. https://doi.org/10.1007/s00253-012-4046-8.
Gao, X. , Xu, N. , Li, S. , & Liu, L. , (2014). Metabolic engineering of candida glabrata for diacetyl production. PLoS One, 9(3), e89854. https://doi.org/10.1371/journal.pone.0089854.
Guo, T. , Kong, J. , Zhang, L. , Zhang, C. , & Hu, S. , (2012). Fine-tuning of the lactate and diacetyl production through promoter engineering in Lactococcus lactis. PLoS One, 7(4), e36296. https://doi.org/10.1371/journal.pone.0036296.
Gupta, S. , & Singh, D. , (2017). Role of genetically modified microorganisms in heavy metal bioremediation. In: Advances in Environmental Biotechnology (pp. 197-214). Springer Singapore. https://doi.org/10.1007/978-981-10-4041-2_12.
Gupta, S. , Pathak, B. , & Fulekar, M. H. , (2015). Molecular approaches for biodegradation of polycyclic aromatic hydrocarbon compounds: A review. In Reviews in Environmental Science and Biotechnology (Vol. 14, No. 2, pp. 241–269). https://doi.org/10.1007/s11157-014-9353-3.
Han, L. , (2004). Genetically modified microorganisms. In: The GMO Handbook pp. 29–29). Humana Press. https://doi.org/10.1007/978-1-59259-801-4_2.
Hasin, A. A. L. , Gurman, S. J. , Murphy, L. M. , Perry, A. , Smith, T. J. , & Gardiner, P. H. E. , (2010). Remediation of chromium(VI) by a methane-oxidizing bacterium. Environmental Science and Technology, 44(1), 400–405. https://doi.org/10.1021/es901723c.
Holowko, M. B. , Wang, H. , Jayaraman, P. , & Poh, C. L. , (2016). Biosensing vibrio cholerae with genetically engineered Escherichia coli. ACS Synthetic Biology, 5(11), 1275–1283. https://doi.org/10.1021/acssynbio.6b00079.
Hopwood, D. A. , (1981). Genetic studies with bacterial protoplasts. In: Annual Review of Microbiology (Vol. 35, pp. 237–272). https://doi.org/10.1146/annurev.mi.35.100181.001321.
Hwang, I. Y. , Koh, E. , Kim, H. R. , Yew, W. S. , & Chang, M. W. , (2016). Reprogrammable microbial cell-based therapeutics against antibiotic-resistant bacteria. In: Drug Resistance Updates (Vol. 27, pp. 59–71). https://doi.org/10.1016/j.drup.2016.06.002.
Hwang, I. Y. , Koh, E. , Wong, A. , March, J. C. , Bentley, W. E. , Lee, Y. S. , & Chang, M. W. , (2017). Engineered probiotic Escherichia coli can eliminate and prevent Pseudomonas aeruginosa gut infection in animal models. Nature Communications, 8(1), 1–11. https://doi.org/10.1038/ncomms15028.
Isabella, V. M. , Ha, B. N. , Castillo, M. J. , Lubkowicz, D. J. , Rowe, S. E. , Millet, Y. A. , Anderson, C. L. , et al. , (2018). Development of a synthetic live bacterial therapeutic for the human metabolic disease phenylketonuria. Nature Biotechnology, 36(9), 857–867. https://doi.org/10.1038/nbt.4222.
Jacob, J. M. , Karthik, C. , Saratale, R. G. , Kumar, S. S. , Prabakar, D. , Kadirvelu, K. , & Pugazhendhi, A. , (2018). Biological approaches to tackle heavy metal pollution: A survey of literature. In: Journal of Environmental Management (Vol. 217, pp. 56–56). Academic Press. https://doi.org/10.1016/j.jenvman.2018.03.077.
Jin, R. F. , Zhou, J. T. , Zhang, A. L. , & Wang, J. , (2008). Bioaugmentation of the decolorization rate of acid red GR by genetically engineered microorganism Escherichia coli JM109 (pGEX-AZR). World Journal of Microbiology and Biotechnology, 24(1), 23–29. https://doi.org/10.1007/s11274-007-9433-4.
Jin, R. , Yang, H. , Zhang, A. , Wang, J. , & Liu, G. , (2009). Bioaugmentation on decolorization of C.I. direct blue 71 by using genetically engineered strain Escherichia coli JM109 (pGEX-AZR). Journal of Hazardous Materials, 163(2, 3), 1123–1128. https://doi.org/10.1016/j.jhazmat.2008.07.067.
Jin, Y. , Luan, Y. , Ning, Y. , & Wang, L. , (2018). Effects and Mechanisms of Microbial Remediation of Heavy Metals in Soil: A Critical Review. Mdpi.com. https://doi.org/10.3390/app8081336.
Johnsborg, O. , Eldholm, V. , & Sigve, H. L. , (2007). Natural Genetic Transformation: Prevalence, Mechanisms and Function. Elsevier. https://doi.org/10.1016/j.resmic.2007.09.004.
Kalnenieks, U. , Balodite, E. , Strähler, S. , Strazdina, I. , Rex, J. , Pentjuss, A. , Fuchino, K. , et al. , (2019). Improvement of acetaldehyde production in Zymomonas mobilis by engineering of its aerobic metabolism. Frontiers in Microbiology, 10, 2533. https://doi.org/10.3389/fmicb.2019.02533.

Kim, J. , & Reed, J. L. , (2010). OptORF: Optimal metabolic and regulatory perturbations for metabolic engineering of microbial strains. BMC Systems Biology, 4. https://doi.org/10.1186/1752-0509-4-53.
Kook, M. C. , Seo, M. J. , Cheigh, C. I. , Lee, S. J. , Pyun, Y. R. , & Park, H. , (2010). Enhancement of γ-aminobutyric acid production by Lactobacillus sakei B2–16 expressing glutamate decarboxylase from Lactobacillus plantarum ATCC 14917. J. Korean Soc. Appl. Biol. Chem, 53(6), 816–820. https://doi.org/10.3839/jksabc.2010.123.
Krappmann, S. , (2017). CRISPR-Cas9, the new kid on the block of fungal molecular biology. Medical Mycology, 55(1), 16–23. https://doi.org/10.1093/mmy/myw097.
Ladero, V. , Ramos, A. , Wiersma, A. , Goffin, P. , Schanck, A. , Kleerebezem, M. , Hugenholtz, J. , et al. , (2007). High-level production of the low-calorie sugar sorbitol by Lactobacillus plantarum through metabolic engineering. Applied and Environmental Microbiology, 73(6), 1864–1872. https://doi.org/10.1128/AEM.02304-06.
Li, G. W. , Burkhardt, D. , Gross, C. , & Weissman, J. S. , (2014). Quantifying absolute protein synthesis rates reveals principles underlying allocation of cellular resources. Cell, 157(3), 624–635. https://doi.org/10.1016/j.cell.2014.02.033.
Li, H. , Cong, Y. , Lin, J. , & Chang, Y. , (2015). Enhanced tolerance and accumulation of heavy metal ions by engineered Escherichia coli expressing Pyrus calleryana phytochelatin synthase. Journal of Basic Microbiology, 55(3), 398–405. https://doi.org/10.1002/jobm.201300670.
Li, Q. , Chen, R. , Li, W. , Qiao, C. L. , & Wu, Y. J. , (2007). A genetically engineered Escherichia coli, expressing the fusion protein of green fluorescent protein and carboxylesterase B1, can be easily detected in the environment following degradation of pesticide residues. Biotechnology Letters, 29(9), 1357–1362. https://doi.org/10.1007/s10529-007-9410-x.
Lim, D. , & Song, M. , (2019). Development of bacteria as diagnostics and therapeutics by genetic engineering. Journal of Microbiology, 57(8), 637–643. https://doi.org/10.1007/s12275-019-9105-8.
Liu, J. , Chan, S. H. J. , Brock-Nannestad, T. , Chen, J. , Lee, S. Y. , Solem, C. , & Jensen, P. R. , (2016). Combining metabolic engineering and biocompatible chemistry for high-yield production of homo-diacetyl and homo-(S,S)-2,3-butanediol. Metabolic Engineering, 36, 57–67. https://doi.org/10.1016/j.ymben.2016.02.008.
Liu, J. , Zhao, B. , Lan, Y. , & Ma, T. , (2021). Enhanced degradation of different crude oils by defined engineered consortia of Acinetobacter venetianus RAG-1 mutants based on their alkane metabolism. Bioresource Technology, 327, 124787. https://doi.org/10.1016/j.biortech.2021.124787.
Liu, L. , Bilal, M. , Duan, X. , & Iqbal, H. M. N. , (2019). Mitigation of environmental pollution by genetically engineered bacteria — Current challenges and future perspectives. In: Science of the Total Environment (Vol. 667, pp. 444–444). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2019.02.390.
Liu, Q. , Zhang, Y. , Li, F. , Li, J. , Sun, W. , & Tian, C. , (2019). Upgrading of efficient and scalable CRISPR-Cas-mediated technology for genetic engineering in thermophilic fungus Myceliophthora thermophila. Biotechnology for Biofuels, 12(1). https://doi.org/10.1186/s13068-019-1637-y.
Liu, S. , Zhang, F. , Chen, J. , & Sun, G. , (2011). Arsenic removal from contaminated soil via volatilization by genetically engineered bacteria under laboratory conditions. Journal of Environmental Sciences, 23(9), 1544–1550. https://doi.org/10.1016/S1001-0742(10)60570-0.
Lu, J. , Guo, C. , Li, J. , Zhang, H. , Lu, G. , Dang, Z. , & Wu, R. , (2013). A fusant of Sphingomonas sp. GY2B and Pseudomonas sp. GP3A with high capacity of degrading phenanthrene. World Journal of Microbiology and Biotechnology, 29(9), 1685–1694. https://doi.org/10.1007/s11274-013-1331-3.
Madyagol, M. , Al-Alami, H. , Levarski, Z. , Drahovská, H. , Turňa, J. , & Stuchlík, S. , (2011). Gene replacement techniques for Escherichia coli genome modification. In: Folia Microbiologica (Vol. 56, No. 3, pp. 253–263). https://doi.org/10.1007/s12223-011-0035-z.
Mallikarjuna, N. , & Yellamma, K. , (2018). Genetic and metabolic engineering of microorganisms for the production of various food products. In: Recent Developments in Applied Microbiology and Biochemistry pp. 167–167). Elsevier. https://doi.org/10.1016/B978-

0-12-816328-3.00013-1.
Mardani, G. , Mahvi, A. H. , Hashemzadeh-Chaleshtori, M. , Naseri, S. , Dehghani, M. H. , & Ghasemi-Dehkordi, P. , (2017). Application of genetically engineered dioxygenase producing pseudomonas putida on decomposition of oil from spiked soil. Jundishapur Journal of Natural Pharmaceutical Products, 12(3 (Supp)). https://doi.org/10.5812/jjnpp.64313.
McAnulty, M. J. , Yen, J. Y. , Freedman, B. G. , & Senger, R. S. , (2012). Genome-scale modeling using flux ratio constraints to enable metabolic engineering of clostridial metabolism in silico. BMC Systems Biology, 6. https://doi.org/10.1186/1752-0509-6-42.
McKay, R. , Ghodasra, M. , Schardt, J. , Quan, D. , Pottash, A. E. , Shang, W. , Jay, S. M. , et al. , (2018). A platform of genetically engineered bacteria as vehicles for localized delivery of therapeutics: Toward applications for Crohn’s disease. Bioengineering & Translational Medicine, 3(3), 209–221. https://doi.org/10.1002/btm2.10113.
Mishra, S. , Sarma, P. M. , & Lal, B. , (2004). Crude oil degradation efficiency of a recombinant Acinetobacter baumannii strain and its survival in crude oil-contaminated soil microcosm. FEMS Microbiology Letters, 235(2), 323–331. https://doi.org/10.1016/j.femsle.2004.05.002.
Mitsui, R. , Yamada, R. , Matsumoto, T. , Yoshihara, S. , Tokumoto, H. , & Ogino, H. , (2020). Construction of lactic acid-tolerant Saccharomyces cerevisiae by using CRISPR-Casmediated genome evolution for efficient d-lactic acid production. Applied Microbiology and Biotechnology, 104(21), 9147–9158. https://doi.org/10.1007/s00253-020-10906-3.
Murphy, K. C. , Campellone, K. G. , & Poteete, A. R. , (2000). PCR-mediated gene replacement in Escherichia coli. In: Gene (Vol. 246). www.elsevier.com/locate/gene (accessed on 12 October 2022).
Na, D. , Yoo, S. M. , Chung, H. , Park, H. , Park, J. H. , & Lee, S. Y. , (2013). Metabolic engineering of Escherichia coli using synthetic small regulatory RNAs. Nature Biotechnology, 31(2), 170–174. https://doi.org/10.1038/nbt.2461.
Nadal, I. , Rico, J. , Pérez-Martínez, G. , Yebra, M. J. , & Monedero, V. (2009). Diacetyl and acetoin production from whey permeate using engineered Lactobacillus casei. Academic. Oup. Com. https://academic.oup.com/jimb/article-abstract/36/9/1233/5993634 (accessed on 12 October 2022).
Nakano, T. , Okaichi, K. , Harada, K. , Matsumoto, H. , Kimura, R. , Yamamoto, K. , Akasaka, S. , & Ohnishi, T. , (1995). Mutations of a shuttle vector plasmid, pZ189, in Escherichia coli induced by boron neutron captured beam (BNCB) containing α-particles. Mutation Research-DNA Repair, 336(2), 153–159. https://doi.org/10.1016/0921-8777(94)00053-9.
Ndimele, P. E. , (2017). The political ecology of oil and gas activities in the Nigerian aquatic ecosystem. In The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem. https://doi.org/10.1016/c2015-0-05649-0.
Nicastro, J. , Sheldon, K. , & Slavcev, R. A. , (2014). Bacteriophage lambda display systems: Developments and applications. In: Applied Microbiology and Biotechnology (Vol. 98, No. 7, pp. 2853–2853). Springer Verlag. https://doi.org/10.1007/s00253-014-5521-1.
Panja, S. , Saha, S. , Jana, B. , & Basu, T. , (2006). Role of membrane potential on artificial transformation of E. coli with plasmid DNA. Journal of Biotechnology, 127, 14–20. https://doi.org/10.1016/j.jbiotec.2006.06.008.
Papagianni, M. , & Legiša, M. , (2014). Increased mannitol production in Lactobacillus reuteri ATCC 55730 production strain with a modified 6-phosphofructo-1-kinase. Journal of Biotechnology, 181, 20–26. https://doi.org/10.1016/j.jbiotec.2014.04.007.
Patel, J. , Zhang, Q. , McKay, R. M. L. , Vincent, R. , & Xu, Z. , (2010). Genetic engineering of Caulobacter crescentus for removal of cadmium from water. Applied Biochemistry and Biotechnology, 160(1), 232–243. https://doi.org/10.1007/s12010-009-8540-0.
Peixoto, R. S. , Vermelho, A. B. , & Rosado, A. S. , (2011). Petroleum-degrading enzymes: Bioremediation and new prospects. In: Enzyme Research (Vol. 2011, No. 1). https://doi.org/10.4061/2011/475193.
Peter, R. , Mojca, J. , & Primož, P. , (2011). Genetically modified organisms (GMOs). In: Encyclopedia of Environmental Health pp. 879–879). Elsevier Inc. https://doi.org/10.1016/B978-0-444-52272-6.00481-5.
Peter, R. , Mojca, J. , & Primož, P. , (2019). Genetically modified organisms (GMOs). In Encyclopedia of Environmental Health (pp. 199–199). Elsevier.

https://doi.org/10.1016/B978-0-444-63951-6.00481-2.
Porter, S. S. , Chang, P. L. , Conow, C. A. , Dunham, J. P. , & Friesen, M. L. , (2017). Association mapping reveals novel serpentine adaptation gene clusters in a population of symbiotic Mesorhizobium. ISME Journal, 11(1), 248–262. https://doi.org/10.1038/ismej.2016.88.
Prakash, D. , Verma, S. , Bhatia, R. , & Tiwary, B. N. , (2011). Risks and precautions of genetically modified organisms. International Scholarly Research Network ISRN Ecology, 2011, 13. https://doi.org/10.5402/2011/369573.
Preston, A. , (2003). Choosing a cloning vector. Methods in Molecular Biology (Clifton, N.J.), 235, 19–26. https://doi.org/10.1385/1-59259-409-3:19.
Rajasulochana, P. , & Preethy, V. , (2016). Comparison on efficiency of various techniques in treatment of waste and sewage water – a comprehensive review. Resource-Efficient Technologies, 2(4), 175–184. https://doi.org/10.1016/j.reffit.2016.09.004.
Ranganathan, S. , Suthers, P. F. , & Maranas, C. D. , (2010). OptForce: An optimization procedure for identifying all genetic manipulations leading to targeted overproductions. PLoS Computational Biology, 6(4). https://doi.org/10.1371/journal.pcbi.1000744.
Rathod, J. , Dhebar, S. , & Archana, G. , (2017). Efficient approach to enhance whole cell azo dye decolorization by heterologous overexpression of Enterococcus sp. L2 azoreductase (azoA) and Mycobacterium vaccae formate dehydrogenase (fdh) in different bacterial systems. International Biodeterioration and Biodegradation, 124, 91–100. https://doi.org/10.1016/j.ibiod.2017.04.023.
Riglar, D. T. , Giessen, T. W. , Baym, M. , Kerns, S. J. , Niederhuber, M. J. , Bronson, R. T. , Kotula, J. W. , et al. , (2017). Engineered bacteria can function in the mammalian gut long-term as live diagnostics of inflammation. Nature Biotechnology, 35(7), 653–658. https://doi.org/10.1038/nbt.3879.
Rivera, A. L. , Magaña-Ortíz, D. , Gómez-Lim, M. , Fernández, F. , & Loske, A. M. , (2014). ScienceDirect Physical Methods for Genetic Transformation of Fungi and Yeast. Elsevier. https://doi.org/10.1016/j.plrev.2014.01.007.
Rodriguez, R. , & Denhardt, D. , (2014). Vectors: A Survey of Molecular Cloning Vectors and Their Uses. https://books.google.com/books?hl=en&lr=&id=PG7iBQAAQBAJ&oi=fnd&pg=PP1&dq=Vectors:+a+survey+of+molecular+cloning+vectors+and+their+uses:+Butterworth-Heinemann.&ots=U06-DzNY0l&sig=3yUuVKKeu0WFg3TVzU6VYWDtUJ8 (accessed on 12 October 2022).
Saeidi, N. , Wong, C. K. , Lo, T. M. , Nguyen, H. X. , Ling, H. , Leong, S. S. J. , Poh, C. L. , & Chang, M. W. , (2011). Engineering microbes to sense and eradicate Pseudomonas aeruginosa, a human pathogen. Molecular Systems Biology, 7. https://doi.org/10.1038/msb.2011.55.
Sandhya, S. , Sarayu, K. , Uma, B. , & Swaminathan, K. , (2008). Decolorizing kinetics of a recombinant Escherichia coli SS125 strain harboring azoreductase gene from Bacillus latrosporus RRK1. Bioresource Technology, 99(7), 2187–2191. https://doi.org/10.1016/j.biortech.2007.05.027.
Sauer, N. J. , Mozoruk, J. , Miller, R. B. , Warburg, Z. J. , Walker, K. A. , Beetham, P. R. , Sch-Opke, C. R. , & Gocal, G. F. W. , (2016). Oligonucleotide-Directed Mutagenesis for Precision Gene Editing, 14(2), 496–502. Wiley Online Library. https://doi.org/10.1111/pbi.12496.
Schroeder, J. W. , Yeesin, P. , Simmons, L. A. , & Wang, J. D. , (2018). Sources of spontaneous mutagenesis in bacteria. In: Critical Reviews in Biochemistry and Molecular Biology (Vol. 53, No. 1, pp. 29–29). Taylor and Francis Ltd. https://doi.org/10.1080/10409238.2017.1394262.
Sehrawat, A. , Phour, M. , Kumar, R. , & Sindhu, S. S. , (2021). Bioremediation of Pesticides: An Eco-Friendly Approach for Environment Sustainability (pp. 23–84). https://doi.org/10.1007/978-981-15-7447-4_2.
Senthil, K. P. , Joshiba, G. J. , Femina, C. C. , Varshini, P. , Priyadharshini, S. , Karthick, A. , & Jothirani, R. , (2019). A Critical Review on Recent Developments in the Low-Cost Adsorption of Dyes from Wastewater. https://doi.org/10.5004/dwt.2019.24613.

Shibai, A. , Takahashi, Y. , Ishizawa, Y. , Motooka, D. , Nakamura, S. , Ying, B. W. , & Tsuru, S. , (2017). Mutation accumulation under UV radiation in Escherichia coli. Scientific Reports, 7(1). https://doi.org/10.1038/s41598-017-15008-1.

Shimazu, M. , Mulchandani, A. , & Chen, W. , (2001). Simultaneous degradation of organophosphorus pesticides and p-nitrophenol by a genetically engineered Moraxella sp. with surface-expressed organophosphorus hydrolase. Biotechnology and Bioengineering, 76(4), 318–324. https://doi.org/10.1002/bit.10095.

Shirshikova, T. V. , Morozova, O. V. , Kamaletdinova, L. K. , Sharipova, M. R. , & Bogomolnaya, L. M. , (2016). Generalized bacteriophage transduction in Serratia marcescens. BioNanoScience, 6(4), 487–489. https://doi.org/10.1007/s12668-016-0268-z.

Singh, N. S. , & Singh, D. K. , (2011). Biodegradation of endosulfan and endosulfan sulfate by Achromobacter xylosoxidans strain C8B in broth medium. Biodegradation, 22(5), 845–857. https://doi.org/10.1007/s10532-010-9442-0.

Son, Y. E. , & Park, H. S. , (2020). Genetic Manipulation and Transformation Methods for Aspergillus spp. Genetic Manipulation and Transformation Methods for Aspergillus spp. Taylor & Francis. https://doi.org/10.1080/12298093.2020.1838115.

Stemmer, W. P. C. , (1994). DNA shuffling by random fragmentation and reassembly: In vitro recombination for molecular evolution. In: Genetics (Vol. 91). https://www.pnas.org/content/91/22/10747.short (accessed on 12 October 2022).

Stewart, G. G. , & Stewart, G. G. , (2017). Yeast genetic manipulation. In Brewing and Distilling Yeasts (pp. 357–387). Springer International Publishing. https://doi.org/10.1007/978-3-319-69126-8_16.

Sybesma, W. , Starrenburg, M. , Kleerebezem, M. , Mierau, I. , De Vos, W. M. , & Hugenholtz, J. , (2003). Increased production of folate by metabolic engineering of Lactococcus lactis. Applied and Environmental Microbiology, 69(6), 3069–3076. https://doi.org/10.1128/AEM.69.6.3069-3076.2003.

Tahri, N. , Bahafid, W. , Sayel, H. , & El Ghachtouli, N. , (2013). Biodegradation: Involved microorganisms and genetically engineered microorganisms. In: Biodegradation - Life of Science. https://doi.org/10.5772/56194.

Tang, X. , Zeng, G. , Fan, C. , Zhou, M. , Tang, L. , Zhu, J. , Wan, J. , et al., (2018). Chromosomal expression of CadR on Pseudomonas aeruginosa for the removal of Cd(II) from aqueous solutions. Science of the Total Environment, 636, 1355–1361. https://doi.org/10.1016/j.scitotenv.2018.04.229.

Tian, F. , Guo, G. , Zhang, C. , Yang, F. , Hu, Z. , Liu, C. , & Wang, S. W. , (2019). Isolation, cloning and characterization of an azoreductase and the effect of salinity on its expression in a halophilic bacterium. International Journal of Biological Macromolecules, 123, 1062–1069. https://doi.org/10.1016/j.ijbiomac.2018.11.175.

Tochhawng, L. , Mishra, V. K. , Passari, A. K. , & Singh, B. P. , (2019). Endophytic Fungi: Role in Dye Decolorization (pp. 1–15). Springer, Cham. https://doi.org/10.1007/978-3-030-03589-1_1.

Vadkertiová, R. , & Sláviková, E. , (2006). Metal tolerance of yeasts isolated from water, soil and plant environments. Journal of Basic Microbiology, 46(2), 145–152. https://doi.org/10.1002/jobm.200510609.

Varjani, S. , Rakholiya, P. , Ng, Y. , You, S. , & Teixeira, J. A. , (2020). Microbial Degradation of Dyes: An Overview. https://doi.org/10.1016/j.biortech.2020.123728.

Wang, L. , Chen, T. , Wang, H. , Wu, X. , Cao, Q. , Wen, K. , Deng, K. Y. , & Xin, H. , (2021). Engineered bacteria of MG1363-pMG36e-GLP-1 attenuated obesity-induced by high fat diet in mice. Frontiers in Cellular and Infection Microbiology, 11. https://doi.org/10.3389/fcimb.2021.595575.

Wood, T. K. , Zhao, H. , & Chen, W. , (2008). Author’s personal copy molecular approaches in bioremediation this review comes from a themed issue on chemical biotechnology edited. Current Opinion in Biotechnology, 19, 572–578. https://doi.org/10.1016/j.copbio.2008.10.003.

Wu, Q. , & Shah, N. P. (2017). High γ-aminobutyric acid production from lactic acid bacteria: emphasis on Lactobacillus brevis as a functional dairy starter. Critical Reviews in Food Science and Nutrition, 57(17), 3661–3672.

Xie, Y. , Yu, F. , Wang, Q. , Gu, X. , & Chen, W. , (2014). Cloning of catechol 2,3-dioxygenase gene and construction of a stable genetically engineered strain for degrading

crude oil. Indian Journal of Microbiology, 54(1), 59–64. https://doi.org/10.1007/s12088-013-0411-2.
Yeh, M. S. , & Chang, J. S. , (2004). Bacterial decolorization of an azo dye with a natural isolate of Pseudomonas luteola and genetically modified Escherichia coli. Journal of Chemical Technology & Biotechnology, 79(12), 1354–1360. https://doi.org/10.1002/jctb.1099.
Yen, J. Y. , Nazem-Bokaee, H. , Freedman, B. G. , Athamneh, A. I. M. , & Senger, R. S. , (2013). Deriving metabolic engineering strategies from genome-scale modeling with flux ratio constraints. Biotechnology Journal, 8(5), 581–594. https://doi.org/10.1002/biot.201200234.
Yuanfan, H. , Jin, Z. , Qing, H. , Qian, W. , Jiandong, J. , & Shunpeng, L. , (2010). Characterization of a fenpropathrin-degrading strain and construction of a genetically engineered microorganism for simultaneous degradation of methyl parathion and fenpropathrin. Journal of Environmental Management, 91(11), 2295–2300. https://doi.org/10.1016/j.jenvman.2010.06.010.
Zafra, G. , Absalón, Á. E. , Anducho-Reyes, M. Á. , Fernandez, F. J. , & Cortés-Espinosa, D. V. , (2017). Construction of PAH-degrading mixed microbial consortia by induced selection in soil. Chemosphere, 172, 120–126. https://doi.org/10.1016/j.chemosphere.2016.12.038.
Zhang, H. , Zhang, X. , & Geng, A. , (2020). Expression of a novel manganese peroxidase from Cerrena unicolor BBP6 in Pichia pastoris and its application in dye decolorization and PAH degradation. Biochemical Engineering Journal, 153, 107402. https://doi.org/10.1016/j.bej.2019.107402.
Zhang, L. , Zhang, Y. , Liu, Q. , Meng, L. , Hu, M. , Lv, M. , Li, K. , et al., (2015). Production of diacetyl by metabolically engineered Enterobacter cloacae. Scientific Reports, 5(1), 1–7. https://doi.org/10.1038/srep09033.
Zhang, M. , Wang, X. , Ahmed, T. , Liu, M. , Wu, Z. , Luo, J. , Tian, Y. , et al., (2020). Identification of genes involved in antifungal activity of Burkholderia seminalis against Rhizoctonia solani using tn5 transposon mutation method. Pathogens, 9(10), 1–15. https://doi.org/10.3390/pathogens9100797.
Zhao, L. , Bao, Y. , Wang, J. , Liu, B. , & An, L. , (2009). Optimization and mechanism of diacetyl accumulation by Enterobacter aerogenes mutant UV-3. World Journal of Microbiology and Biotechnology, 25(1), 57–64. https://doi.org/10.1007/s11274-008-9862-8.
Zhao, X. W. , Zhou, M. H. , Li, Q. B. , Lu, Y. H. , He, N. , Sun, D. H. , & Deng, X. , (2005). Simultaneous mercury bioaccumulation and cell propagation by genetically engineered Escherichia coli. Process Biochemistry, 40(5), 1611–1616. https://doi.org/10.1016/j.procbio.2004.06.014.
Zhou, Y. , Wei, J. , Shao, N. , & Wei, D. , (2013). Construction of a genetically engineered microorganism for phenanthrene biodegradation. Journal of Basic Microbiology, 53(2), 188–194. https://doi.org/10.1002/jobm.201100322.

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Abdelraheem, A. , Fang, D. D. , & Zhang, J. , (2018). Quantitative trait locus mapping of drought and salt tolerance in an introgressed recombinant inbred line population of upland cotton under the greenhouse and field conditions. Euphytica., 214(1), 1-20.
Abdurakhmonov, I. Y. , & Abdukarimov, A. , (2008). Application of association mapping to understanding the genetic diversity of plant germplasm resources. International Journal of Plant Genomics, 2008.
Agrawal, R. L. , (1998). Fundamentals of Plant Breeding and Hybrid Seed Production. Science Publishers, Inc.
Anderson, M. , Taliaferro, C. , Martin, D. , & Anderson, C. , (2001). Comparative DNA profiling of U-3 turf bermudagrass strains. Crop Science, 41(4), 1184-1189.
Ashraf, M. , & Harris, P. , (2005). Abiotic Stresses: Plant Resistance Through Breeding and Molecular Approaches. CRC Press.
Aslam, M. , Jiang, C. , Wright, R. , & Paterson, A. , (2000). Identification of Molecular Markers Linked to Leaf Curl Virus Disease Resistance in Cotton. 11(4), 277-280.

Babu, R. C. , Nguyen, B. D. , Chamarerk, V. , Shanmugasundaram, P. , Chezhian, P. , Jeyaprakash, P. , Ganesh, S. , et al. , (2003). Genetic analysis of drought resistance in rice by molecular markers: Association between secondary traits and field performance. Crop Science, 43(4), 1457-1469.
Bailey, D. C. , (1983). Isozymic variation and plant breeders' rights. In: Developments in Plant Genetics and Breeding (Vol. 1, pp. 425-440). Elsevier.
Balkrishna, R. A. , & Shankarrao, S. S. , (2013). In vitro screening and molecular genetic markers associated with salt tolerance in maize. African Journal of Biotechnology, 12(27), 4251-4255.
Batley, J. , Barker, G. , O'Sullivan, H. , Edwards, K. J. , & Edwards, D. , (2003). Mining for single nucleotide polymorphisms and insertions/deletions in maize expressed sequence tag data. Plant Physiology, 132(1), 84-91.
Beebe, S. , Skroch, P. W. , Tohme, J. , Duque, M. , Pedraza, F. , & Nienhuis, J. , (2000). Structure of genetic diversity among common bean landraces of Middle American origin based on correspondence analysis of RAPD. Crop Science, 40(1), 264-273.
Bhattramakki, D. , Dolan, M. , Hanafey, M. , Wineland, R. , Vaske, D. , Register, J. C. , Tingey, S. V. , & Rafalski, A. , (2002). Insertion-deletion polymorphisms in 3′ regions of maize genes occur frequently and can be used as highly informative genetic markers. Plant Molecular Biology, 48(5), 539-547.
Bhutta, W. M. , & Amjad, M. , (2015). Molecular characterization of salinity tolerance in wheat (Triticum aestivum L.). Archives of Agronomy and Soil Science, 61(11), 1641-1648.
Bizimana, J. B. , Luzi-Kihupi, A. , Murori, R. W. , & Singh, R. , (2017). Identification of quantitative trait loci for salinity tolerance in rice (Oryza sativa L.) using IR29/hasawi mapping population. Journal of Genetics, 96(4), 571-582.
Bohnert, H. J. , Gong, Q. , Li, P. , & Ma, S. , (2006). Unraveling abiotic stress tolerance mechanisms-getting genomics going. Current Opinion in Plant Biology., 9(2), 180-188.
Bolek, Y. , El-Zik, K. M. , Pepper, A. E. , Bell, A. A. , Magill, C. W. , Thaxton, P. M. , & Reddy, O. U. K. , (2005). Mapping of verticillium wilt resistance genes in cotton. Plant Science, 168(6), 1581-1590. doi: https://doi.org/10.1016/j.plantsci.2005.02.008.
Buu, B. C. , Ha, P. T. T. , Tam, B. P. , Nhien, T. T. , Van, H. N. , Phuoc, N. T. , Giang, L. H. , & Lang, N. T. , (2014). Quantitative trait loci associated with heat tolerance in rice (Oryza sativa L.). Plant Breeding and Biotechnology, 2(1), 14-24.
Castagna, R. , Gnocchi, S. , Perenzin, M. , & Heun, M. , (1997). Genetic variability of the wild diploid wheat Triticum Urartu revealed by RFLP and RAPD markers. Theoretical and Applied Genetics, 94(3, 4), 424-430.
Chen, Q. , Song, J. , Du, W. P. , Xu, L. Y. , Jiang, Y. , Zhang, J. , Xiang, X. L. , & Yu, G. R. , (2017). Identification, mapping, and molecular marker development for Rgsr8. 1: A new quantitative trait locus conferring resistance to Gibberella stalk rot in maize (Zea mays L.). Frontiers in Plant Science, 8, 1355.
Choudhary, S. , Gaur, R. , Gupta, S. , & Bhatia, S. , (2012). EST-derived genic molecular markers: Development and utilization for generating an advanced transcript map of chickpea. Theoretical and Applied Genetics, 124(8), 1449-1462. doi:10.1007/s00122-012-1800-3.
Collard, B. C. , Jahufer, M. , Brouwer, J. , & Pang, E. , (2005). An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts. Euphytica, 142(1), 169-196.
Collins, N. C. , Tardieu, F. , & Tuberosa, R. , (2008). Quantitative trait loci and crop performance under abiotic stress: Where do we stand? Plant Physiology, 147(2), 469-486.
Dahlberg, J. , Zhang, X. , Hart, G. , & Mullet, J. , (2002). Comparative assessment of variation among sorghum germplasm accessions using seed morphology and RAPD measurements. Crop Science, 42(1), 291-296.
Daugrois, J. H. , Grivet, L. , Roques, D. , Hoarau, J. Y. , Lombard, H. , Glaszmann, J. C. , & D'Hont, A. , (1996). A putative major gene for rust resistance linked with a RFLP marker in sugarcane cultivar 'R570'. Theoretical and Applied Genetics, 92(8), 1059-1064. doi: 10.1007/BF00224049.
De Leon, T. B. , Linscombe, S. , Gregorio, G. , & Subudhi, P. K. , (2015). Genetic variation in Southern USA rice genotypes for seedling salinity tolerance. Frontiers in Plant Science, 6, 374.

Doğan, İ. , Kekeç, G. , Özyiğit, İ. İ. , & Sakçalı, M. S. , (2012). Salinity Induced Changes in Cotton (Gossypium hirsutum L.). Pakistan Journal of Botany, 44(SPL.ISS.1), 21-25.
Dolferus, R. , Thavamanikumar, S. , Sangma, H. , Kleven, S. , Wallace, X. , Forrest, K. , Rebetzke, G. , et al. , (2019). Determining the genetic architecture of reproductive stage drought tolerance in wheat using a correlated trait and correlated marker effect model. G3: Genes, Genomes, Genetics, 9(2), 473-489.
Dussle, C. , Quint, M. , Xu, M. , Melchinger, A. , & Lübberstedt, T. , (2002). Conversion of AFLP fragments tightly linked to SCMV resistance genes Scmv1 and Scmv2 into simple PCR-based markers. Theoretical and Applied Genetics, 105(8), 1190-1195.
Duvick, D. N. , (2001). Biotechnology in the 1930s: The development of hybrid maize. Nature Reviews Genetics, 2(1), 69-74.
Eagles, H. A. , Bariana, H. S. , Ogbonnaya, F. C. , Rebetzke, G. J. , Hollamby, G. , Henry, R. J. , Henschke, P. , & Carter, M. , (2001). Implementation of markers in Australian wheat breeding. Australian Journal of Agricultural Research, 52(12), 1349-1356.
Falque, M. , Décousset, L. , Dervins, D. , Jacob, A. M. , Joets, J. , Martinant, J. P. , Raffoux, X. , et al. , (2005). Linkage mapping of 1454 new maize candidate gene loci. Genetics, 170(4), 1957-1966.
Funatsuki, H. , Suzuki, M. , Hirose, A. , Inaba, H. , Yamada, T. , Hajika, M. , Komatsu, K. , et al. , (2014). Molecular basis of a shattering resistance boosting global dissemination of soybean. Proceedings of the National Academy of Sciences, 111(50), 17797-17802.
García-Moreno, M. J. , Velasco, L. , & Pérez-Vich, B. , (2010). Transferability of non-genic microsatellite and gene-based sunflower markers to safflower. Euphytica, 175(2), 145-150. doi: 10.1007/s10681-010-0139-6.
Graner, A. , Ludwig, W. F. , & Melchinger, A. E. , (1994). Relationships among European barley germplasm: II. Comparison of RFLP and pedigree data. Crop Science, 34(5), 1199-1205.
Graner, A. , Streng, S. , Drescher, A. , Jin, Y. , Borovkova, I. , & Steffenson, B. , (2000). Molecular mapping of the leaf rust resistance gene Rph7 in barley. Plant Breeding, 119(5), 389-392.
Hansen, M. , Kraft, T. , Ganestam, S. , Saell, T. , & Nilsson, N. O. , (2001). Linkage disequilibrium mapping of the bolting gene in sea beet using AFLP markers. Genetics Research, 77(1), 61-66.
Hao, Z. , Li, X. , Xie, C. , Weng, J. , Li, M. , Zhang, D. , Liang, X. , et al. , (2011). Identification of functional genetic variations underlying drought tolerance in maize using SNP markers. Journal of Integrative Plant Biology, 53(8), 641-652.
Hoeschele, I. , (2004). Mapping quantitative trait loci in outbred pedigrees. Handbook of Statistical Genetics.
Howarth, C. J. (2005). Genetic improvements of tolerance to high temperature. Abiotic Stresses: Plant Resistance Through Breeding and Molecular Approaches. Howarth Press Inc., New York, 277-300.
Huseynova, I. M. , & Rustamova, S. M. , (2010). Screening for drought stress tolerance in wheat genotypes using molecular markers. Proc. ANAS (Biol. Sci.), 65(5, 6), 132-139.
Hussain, B. , Lucas, S. J. , Ozturk, L. , & Budak, H. , (2017). Mapping QTLs conferring salt tolerance and micronutrient concentrations at seedling stage in wheat. Scientific Reports, 7(1), 1-14.
Iglesias-García, R. , Prats, E. , Fondevilla, S. , Satovic, Z. , & Rubiales, D. , (2015). Quantitative trait loci associated with drought adaptation in pea (Pisum sativum L.). Plant Molecular Biology Reporter, 33(6), 1768-1778.
Jaikishan, I. , Rajendrakumar, P. , Madhusudhana, R. , Elangovan, M. , & Patil, J. V. , (2015). Development and utility of PCR-based intron polymorphism markers in sorghum [Sorghum bicolor (L.) Moench]. Journal of Crop Science and Biotechnology., 18(5), 309-318. doi: 10.1007/s12892-015-0015-y.
Jain, S. M. , (2001). Tissue culture-derived variation in crop improvement. Euphytica, 118(2), 153-166.
Jain, S. , Kumar, A. , Mamidi, S. , & McPhee, K. , (2014). Genetic diversity and population structure among pea (Pisum sativum L.) cultivars as revealed by simple sequence repeat and novel genic markers. Molecular Biotechnology, 56(10), 925-938. doi: 10.1007/s12033-

014-9772-y.
Jeffreys, A. J. , Wilson, V. , & Thein, S. L. , (1985). Hypervariable ‘minisatellite’ regions in human DNA. Nature, 314(6006), 67-73.
Jeon, J. S. , Chen, D. , Yi, G. H. , Wang, G. , & Ronald, P. , (2003). Genetic and physical mapping of Pi5 (t), a locus associated with broad-spectrum resistance to rice blast. Molecular Genetics and Genomics, 269(2), 280-289.
Jiang, G. L. , (2013). Molecular markers and marker-assisted breeding in plants. Plant Breeding from Laboratories to Fields, 45-83.
Jones, E. , Sullivan, H. , Bhattramakki, D. , & Smith, J. , (2007). A comparison of simple sequence repeat and single nucleotide polymorphism marker technologies for the genotypic analysis of maize (Zea mays L.). Theoretical and Applied Genetics, 115(3), 361-371.
Kalia, R. K. , Rai, M. K. , Kalia, S. , Singh, R. , & Dhawan, A. , (2011). Microsatellite markers: An overview of the recent progress in plants. Euphytica, 177(3), 309-334.
Kang, Y. J. , Lee, T. , Lee, J. , Shim, S. , Jeong, H. , Satyawan, D. , Kim, M. Y. , & Lee, S. H. , (2016). Translational genomics for plant breeding with the genome sequence explosion. Plant Biotechnology Journal, 14(4), 1057-1069.
Karp, A. , (1997). Molecular Tools in Plant Genetic Resources Conservation: A Guide to the Technologies. Bioversity International.
Kebede, H. , Subudhi, P. , Rosenow, D. , & Nguyen, H. , (2001). Quantitative trait loci influencing drought tolerance in grain sorghum (Sorghum bicolor L. Moench). Theoretical and Applied Genetics, 103(2, 3), 266-276.
Kirigwi, F. , Van, G. M. , Brown-Guedira, G. , Gill, B. , Paulsen, G. M. , & Fritz, A. , (2007). Markers associated with a QTL for grain yield in wheat under drought. Molecular Breeding, 20(4), 401-413.
Klein, A. , Houtin, H. , Rond, C. , Marget, P. , Jacquin, F. , Boucherot, K. , Huart, M. , et al. , (2014). QTL analysis of frost damage in pea suggests different mechanisms involved in frost tolerance. Theoretical and Applied Genetics., 127(6), 1319-1330.
Koebner, R. M. , & Varshney, R. K. , (2006). Development and application of genomic models for large-crop plant genomes. Model Plants and Crop Improvement, 1(9).
Kraakman, A. T. , Niks, R. E. , Van, D. B. P. M. , Stam, P. , & Van, E. F. A. , (2004). Linkage disequilibrium mapping of yield and yield stability in modern spring barley cultivars. Genetics, 168(1), 435-446.
Kraakman, A. , Martinez, F. , Mussiraliev, B. , Van, E. F. , & Niks, R. , (2006). Linkage disequilibrium mapping of morphological, resistance, and other agronomically relevant traits in modern spring barley cultivars. Molecular Breeding, 17(1), 41-58.
Kumawat, G. , Gupta, S. , Ratnaparkhe, M. B. , Maranna, S. , & Satpute, G. K. , (2016). QTLomics in soybean: A way forward for translational genomics and breeding. Frontiers in Plant Science, 7, 1852.
Kumpatla, S. P. , Buyyarapu, R. , Abdurakhmonov, I. Y. , & Mammadov, J. A. , (2012). Genomics-assisted plant breeding in the 21st century: Technological advances and progress. In: Plant Breeding. Intechopen.
Lai, Z. , Livingstone, K. , Zou, Y. , Church, S. , Knapp, S. , Andrews, J. , & Rieseberg, L. , (2005). Identification and mapping of SNPs from ESTs in sunflower. Theoretical and Applied Genetics, 111(8), 1532-1544.
Lecomte, L. , Duffe, P. , Buret, M. , Servin, B. , & Causse, M. , (2004). Marker-assisted introgression of five QTLs controlling fruit quality traits into three tomato lines revealed interactions between QTLs and genetic backgrounds. Theoretical and Applied Genetics, 109(3), 658-668.
Li, G. , & Quiros, C. F. , (2001). Sequence-related amplified polymorphism (SRAP), a new marker system based on a simple PCR reaction: Its application to mapping and gene tagging in Brassica. Theoretical and Applied Genetics, 103(2, 3), 455-461.
Li, G. , Xu, X. , Tan, C. , Carver, B. F. , Bai, G. , Wang, X. , Bonman, J. M. , Wu, Y. , Hunger, R. , & Cowger, C. , (2019). Identification of powdery mildew resistance loci in wheat by integrating genome-wide association study (GWAS) and linkage mapping. The Crop Journal, 7(3), 294-306. doi: https://doi.org/10.1016/j.cj.2019.01.005.
Li, Z. , & Nelson, R. L. , (2002). RAPD marker diversity among cultivated and wild soybean accessions from four Chinese provinces. Crop Science, 42(5), 1737-1744.

Liang, X. , Chen, X. , Hong, Y. , Liu, H. , Zhou, G. , Li, S. , & Guo, B. , (2009). Utility of EST-derived SSR in cultivated peanut (Arachis hypogaea L.) and Arachis wild species. BMC Plant Biology, 9(1), 35. doi: 10.1186/1471-2229-9-35.
Lin, K. H. , Lo, H. F. , Lee, S. P. , George, K. C. , Chen, J. T. , & Yeh, W. L. , (2006). RAPD markers for the identification of yield traits in tomatoes under heat stress via bulked segregant analysis. Hereditas, 143(2006), 142-154.
Linh, L. H. , Linh, T. H. , Xuan, T. D. , Ham, L. H. , Ismail, A. M. , & Khanh, T. D. , (2012). Molecular breeding to improve salt tolerance of rice (Oryza sativa L.) in the Red River delta of Vietnam. International Journal of Plant Genomics, 2012.
Liu, B. H. , (2017). Statistical Genomics: Linkage, Mapping, and QTL Analysis. CRC press.
Liu, B. , Kanazawa, A. , Matsumura, H. , Takahashi, R. , Harada, K. , & Abe, J. , (2008). Genetic redundancy in soybean photoresponses associated with duplication of the phytochrome A gene. Genetics, 180(2), 995-1007.
Liu, R. , Fang, L. , Yang, T. , Zhang, X. , Hu, J. , Zhang, H. , Han, W. , et al. , (2017). Markertrait association analysis of frost tolerance of 672 worldwide pea (Pisum sativum L.) collections. Scientific Reports, 7(1), 1-10.
Mago, R. , Spielmeyer, W. , Lawrence, G. , Lagudah, E. , Ellis, J. , & Pryor, A. , (2002). Identification and mapping of molecular markers linked to rust resistance genes located on chromosome 1RS of rye using wheat-rye translocation lines. Theoretical and Applied Genetics, 104(8), 1317-1324.
Mammadov, J. , Aggarwal, R. , Buyyarapu, R. , & Kumpatla, S. , (2012). SNP markers and their impact on plant breeding. International Journal of Plant Genomics, 2012.
Massman, J. , Cooper, B. , Horsley, R. , Neate, S. , Dill-Macky, R. , Chao, S. , Dong, Y. , et al., (2011). Genome-wide association mapping of fusarium head blight resistance in contemporary barley breeding germplasm. Molecular Breeding., 27(4), 439-454. doi: 10.1007/s11032-010-9442-0.
Miles, C. , & Wayne, M. , (2008). Quantitative trait locus (QTL) analysis. Nature Education, 1(1), 208.
Mohammadi-Nejad, G. , Arzani, A. , Reza, A. , Singh, R. , & Gregorio, G. , (2008). Assessment of rice genotypes for salt tolerance using microsatellite markers associated with the saltol QTL. African Journal of Biotechnology, 7(6).
Mondal, S. , Badigannavar, A. M. , & D'Souza, S. F. , (2012). Development of genic molecular markers linked to a rust resistance gene in cultivated groundnut (Arachis hypogaea L.). Euphytica., 188(2), 163-173. doi: 10.1007/s10681-011-0619-3.
Mondini, L. , Noorani, A. , & Pagnotta, M. A. , (2009). Assessing plant genetic diversity by molecular tools. Diversity, 1(1), 19-35.
Moose, S. P. , & Mumm, R. H. , (2008). Molecular plant breeding as the foundation for 21st century crop improvement. Plant Physiology, 147(3), 969-977.
Moreau, L. , Charcosset, A. , Hospital, F. , & Gallais, A. , (1998). Marker-assisted selection efficiency in populations of finite size. Genetics, 148(3), 1353-1365.
Munns, R. , & Tester, M. , (2008). Mechanisms of salinity tolerance. Annu. Rev. Plant Biol., 59, 651-681.
Najeb, B. M. , Al-Doss, A. A. , Elshafei, A. A. , & Moustafa, K. A. , (2011). Identification of new microsatellite marker linked to the grain filling rate as indicator for heat tolerance genes in F2 wheat population. Australian Journal of Crop Science, 5(2), 104.
Nicot, N. , Chiquet, V. , Gandon, B. , Amilhat, L. , Legeai, F. , Leroy, P. , Bernard, M. , & Sourdille, P. , (2004). Study of simple sequence repeat (SSR) markers from wheat expressed sequence tags (ESTs). Theoretical and Applied Genetics, 109(4), 800-805.
Nirgude, M. , Babu, B. K. , Shambhavi, Y. , Singh, U. M. , Upadhyaya, H. D. , & Kumar, A. , (2014). Development and molecular characterization of genic molecular markers for grain protein and calcium content in finger millet (Eleusine coracana (L.) Gaertn.). Molecular Biology Reports, 41(3), 1189-1200. doi: 10.1007/s11033-013-2825-7.
Nordborg, M. , Borevitz, J. O. , Bergelson, J. , Berry, C. C. , Chory, J. , Hagenblad, J. , Kreitman, M. , et al. , (2002). The extent of linkage disequilibrium in Arabidopsis thaliana. Nature Genetics, 30(2), 190-193.
Oropeza, M. , & Degarcia, E. , (1997). Use of molecular markers for identification of sugar cane varieties (Saccharum sp). Phyton-International Journal of Experimental Botany, 61(1,

2), 81-85.
Parh, D. K. , Jordan, D. R. , Aitken, E. A. B. , Mace, E. S. , Jun-Ai, P. , McIntyre, C. L. , & Godwin, I. D. , (2008). QTL analysis of ergot resistance in sorghum. Theoretical and Applied Genetics, 117(3), 369-382. doi: 10.1007/s00122-008-0781-8.
Park, Y. H. , Alabady, M. S. , Ulloa, M. , Sickler, B. , Wilkins, T. A. , Yu, J. , Stelly, D. M. , et al. , (2005). Genetic mapping of new cotton fiber loci using EST-derived microsatellites in an interspecific recombinant inbred line cotton population. Molecular Genetics and Genomics, 274(4), 428-441.
Poortavakoli, S. , Sheidai, M. , Alishah, O. , & Noormohammadi, Z. , (2017). Genetic diversity analysis in drought stress tolerant cottons. The Nucleus, 60(1), 57-62.
Popi, J. , Rajnpreht, J. , Kannenberg, L. , & Pauls, K. , (2000). Random amplified polymorphic DNA-based evaluation of diversity in the hierarchical, open-ended population enrichment maize breeding system. Crop Science, 40(3), 619-625.
Pupilli, F. , Labombarda, P. , Scotti, C. , & Arcioni, S. , (2000). RFLP analysis allows for the identification of alfalfa ecotypes. Plant Breeding, 119(3), 271-276.
Qiu, L. , Yang, C. , Tian, B. , Yang, J. B. , & Liu, A. , (2010). Exploiting EST databases for the development and characterization of EST-SSR markers in castor bean (Ricinus communis L.). BMC Plant Biology, 10(1), 278. doi: 10.1186/1471-2229-10-278.
Rafalski, J. A. , (2002). Novel genetic mapping tools in plants: SNPs and LD-based approaches. Plant Science, 162(3), 329-333.
Ragot, M. , & Hoisington, D. , (1993). Molecular markers for plant breeding: Comparisons of RFLP and RAPD genotyping costs. Theoretical and Applied Genetics, 86(8), 975-984.
Rashed, M. , Sabry, S. , Atta, A. , & Mostafa, A. , (2010). Development of RAPD markers associated with drought tolerance in bread wheat (Triticum aestivum). Egyptian Journal of Genetics and Cytology, 39(1).
Ribaut, J. M. , & Betrán, J. , (1999). Single large-scale marker-assisted selection (SLSMAS). Molecular Breeding, 5(6), 531-541.
Roy, J. K. , Smith, K. P. , Muehlbauer, G. J. , Chao, S. , Close, T. J. , & Steffenson, B. J. , (2010). Association mapping of spot blotch resistance in wild barley. Molecular Breeding, 26(2), 243-256. doi: 10.1007/s11032-010-9402-8.
Sabouri, H. , & Sabouri, A. , (2008). New evidence of QTLs attributed to salinity tolerance in rice. African Journal of Biotechnology, 7(24).
Saeed, M. , Wangzhen, G. , & Tianzhen, Z. , (2014). Association mapping for salinity tolerance in cotton (‘Gossypium hirsutum’ L.) germplasm from US and diverse regions of China. Australian Journal of Crop Science, 8(3).
Saleh, B. , (2016). DNA changes in cotton (Gossypium hirsutum L.) under salt stress as revealed by RAPD marker. Advances in Horticultural Science, 30(1), 13-22.
Santos, F. R. C. , Pinto, L. R. , Carlini-Garcia, L. A. , Gazaffi, R. , Mancini, M. C. , Gonçalves, B. S. , Medeiros, C. N. F. , et al., (2015). Marker-trait association and epistasis for brown rust resistance in sugarcane. Euphytica, 203(3), 533-547. doi:10.1007/s10681-014-1257-3.
Sardesai, N. , Kumar, A. , Rajyashri, K. , Nair, S. , & Mohan, M. , (2002). Identification and mapping of an AFLP marker linked to Gm7, a gall midge resistance gene and its conversion to a SCAR marker for its utility in marker aided selection in rice. Theoretical and Applied Genetics, 105(5), 691-698.
Sasanuma, T. , Miyashita, N. , & Tsunewaki, K. , (1996). Wheat phylogeny determined by RFLP analysis of nuclear DNA. 3. Intra-and interspecific variations of five Aegilops sitopsis species. Theoretical and Applied Genetics, 92(8), 928-934.
Sbei, H. , Sato, K. , Shehzad, T. , Harrabi, M. , & Okuno, K. , (2014). Detection of QTLs for salt tolerance in Asian barley (Hordeum vulgare L.) by association analysis with SNP markers. Breeding Science, 64(4), 378-388.
Shao, H. B. , Liang, Z. S. , Shao, M. A. , & Sun, Q. , (2005). Dynamic changes of antioxidative enzymes of 10 wheat genotypes at soil water deficits. Colloids and Surfaces B: Biointerfaces, 42(3, 4), 187-195.
Shasany, A. , Darokar, M. , Dhawan, S. , Gupta, A. , Gupta, S. , Shukla, A. , Patra, N. , & Khanuja, S. P. , (2005). Use of RAPD and AFLP markers to identify inter-and intraspecific hybrids of Mentha. Journal of Heredity, 96(5), 542-549.

Siedler, H. , Messmer, M. , Schachermayr, G. , Winzeler, H. , Winzeler, M. , & Keller, B. , (1994). Genetic diversity in European wheat and spelt breeding material based on RFLP data. Theoretical and Applied Genetics, 88(8), 994-1003.
Sonah, H. , Bastien, M. , Iquira, E. , Tardivel, A. , Légaré, G. , Boyle, B. , Normandeau, É. , et al. , (2013). An improved genotyping by sequencing (GBS) approach offering increased versatility and efficiency of SNP discovery and genotyping. PloS One, 8(1), e54603.
Soto-Cerda, B. J. , Saavedra, H. U. , Navarro, C. N. , & Ortega, P. M. , (2011). Characterization of novel genic SSR markers in Linum usitatissimum (L.) and their transferability across eleven Linum species. Electronic Journal of Biotechnology, 14(2), 4. http://dx.doi.org/10.2225/vol14-issue2-fulltext-6.
Spaniolas, S. , May, S. T. , Bennett, M. J. , & Tucker, G. A. , (2006). Authentication of coffee by means of PCR-RFLP analysis and lab-on-a-chip capillary electrophoresis. Journal of Agricultural and Food Chemistry, 54(20), 7466-7470.
Suenaga, K. , Singh, R. , Huerta-Espino, J. , & William, H. , (2003). Microsatellite markers for genes Lr34/Yr18 and other quantitative trait loci for leaf rust and stripe rust resistance in bread wheat. Phytopathology, 93(7), 881-890.
Tadesse, W. , Suleiman, S. , Tahir, I. , Sanchez-Garcia, M. , Jighly, A. , Hagras, A. , Thabet, S. , & Baum, M. , (2019). Heat-tolerant QTLs associated with grain yield and its components in spring bread wheat under heat-stressed environments of Sudan and Egypt. Crop Science, 59(1), 199-211.
Tanksley, S. D. , Young, N. D. , Paterson, A. H. , & Bonierbale, M. , (1989). RFLP mapping in plant breeding: New tools for an old science. Bio/Technology, 7(3), 257-264.
Upadhyaya, H. D. , Wang, Y. H. , Sharma, R. , & Sharma, S. , (2013). Identification of genetic markers linked to anthracnose resistance in sorghum using association analysis. Theoretical and Applied Genetics, 126(6), 1649-1657. doi: 10.1007/s00122-013-2081-1.
Varshney, R. K. , Kudapa, H. , Pazhamala, L. , Chitikineni, A. , Thudi, M. , Bohra, A. , Gaur, P. M. , et al. , (2015). Translational genomics in agriculture: Some examples in grain legumes. Critical Reviews in Plant Sciences, 34(1-3), 169-194.
Wainaina, C. M. , Makihara, D. , Nakamura, M. , Ikeda, A. , Suzuki, T. , Mizukami, Y. , Nonoyama, T. , et al. , (2018). Identification and validation of QTLs for cold tolerance at the booting stage and other agronomic traits in a rice cross of a Japanese tolerant variety, Hananomai, and a NERICA parent, WAB56-104. Plant Production Science, 21(2), 132-143.
Wan, H. , Chen, L. , Guo, J. , Li, Q. , Wen, J. , Yi, B. , Ma, C. , et al., (2017). Genome-wide association study reveals the genetic architecture underlying salt tolerance-related traits in rapeseed (Brassica napus L.). Frontiers in Plant Science, 8, 593.
Wang, Z. , Li, J. , Luo, Z. , Huang, L. , Chen, X. , Fang, B. , Li, Y. , Chen, J. , & Zhang, X. , (2011). Characterization and development of EST-derived SSR markers in cultivated sweetpotato (Ipomoea batatas). BMC Plant Biology, 11(1), 139. doi: 10.1186/1471-2229-11-139.
Watanabe, S. , Xia, Z. , Hideshima, R. , Tsubokura, Y. , Sato, S. , Yamanaka, N. , Takahashi, R. , et al. , (2011). A map-based cloning strategy employing a residual heterozygous line reveals that the GIGANTEA gene is involved in soybean maturity and flowering. Genetics., 188(2), 395-407.
Weiland, J. , & Yu, M. , (2003). A cleaved amplified polymorphic sequence (CAPS) marker associated with root-knot nematode resistance in sugar beet. Crop Science, 43(5), 1814-1818.
Williams, J. G. , Kubelik, A. R. , Livak, K. J. , Rafalski, J. A. , & Tingey, S. V. , (1990). DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. Nucleic Acids Research, 18(22), 6531-6535.
Williams, K. , (2003). The molecular genetics of disease resistance in barley. Australian Journal of Agricultural Research, 54(12), 1065-1079.
Wright, S. I. , Bi, I. V. , Schroeder, S. G. , Yamasaki, M. , Doebley, J. F. , McMullen, M. D. , & Gaut, B. S. , (2005). The effects of artificial selection on the maize genome. Science, 308(5726), 1310-1314.
Wu, R. , Ma, C. , & Casella, G. , (2007). Statistical Genetics of Quantitative Traits: Linkage, Maps and QTL. Springer Science & Business Media.

Xiao, Y. , Pan, Y. , Luo, L. , Zhang, G. , Deng, H. , Dai, L. , Liu, X. , et al. , (2011). Quantitative trait loci associated with seed set under high temperature stress at the flowering stage in rice (Oryza sativa L.). Euphytica., 178(3), 331-338.

Xu, M. , Xu, Z. , Liu, B. , Kong, F. , Tsubokura, Y. , Watanabe, S. , Xia, Z. , et al., (2013). Genetic variation in four maturity genes affects photoperiod insensitivity and PHYAregulated post-flowering responses of soybean. BMC Plant Biology, 13(1), 1-14.

Xu, Y. , (2010). Molecular Plant Breeding. CABI.

Xue, D. , Huang, Y. , Zhang, X. , Wei, K. , Westcott, S. , Li, C. , Chen, M. , et al. , (2009). Identification of QTLs associated with salinity tolerance at late growth stage in barley. Euphytica, 169(2), 187-196.

Yan, J. , Kandianis, C. B. , Harjes, C. E. , Bai, L. , Kim, E. H. , Yang, X. , Skinner, D. J. , et al. , (2010). Rare genetic variation at Zea mays crtRB1 increases β-carotene in maize grain. Nature Genetics, 42(4), 322-327.

Yan, J. , Warburton, M. , & Crouch, J. , (2011). Association mapping for enhancing maize (Zea mays L.) genetic improvement. Crop Science, 51(2), 433-449.

Zabeau, M. , (1993). Selective Restriction Fragment Amplification: A General Method for DNA Fingerprinting. European Patent Application 92402629.7.

Zhang, G. L. , Chen, L. Y. , Xiao, G. Y. , Xiao, Y. H. , Chen, X. B. , & Zhang, S. T. , (2009). Bulked segregant analysis to detect QTL related to heat tolerance in rice (Oryza sativa L.) using SSR markers. Agricultural Sciences in China, 8(4), 482-487.

Zhang, J. , Song, Q. , Cregan, P. B. , Nelson, R. L. , Wang, X. , Wu, J. , & Jiang, G. L. , (2015). Genome-wide association study for flowering time, maturity dates and plant height in early maturing soybean (Glycine max) germplasm. BMC Genomics, 16(1), 1-11.

Zhou, G. A. , Chang, R. Z. , & Qiu, L. J. , (2010). Overexpression of soybean ubiquitinconjugating enzyme gene GmUBC2 confers enhanced drought and salt tolerance through modulating abiotic stress-responsive gene expression in Arabidopsis. Plant Molecular Biology, 72(4), 357-367.

Zhu, C. , Gore, M. , Buckler, E. S. , & Yu, J. , (2008). Status and prospects of association mapping in plants. The Plant Genome, 1(1).