Microorganisms for Sustainability 42
Series Editor: Naveen Kumar Arora

Natarajan Amaresan
Dhanasekaran Dharumadurai
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Industrial Microbiology Based Entrepreneurship

Making Money from Microbes

Springer

Microorganisms for Sustainability

Volume 42

Series Editor

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Microorganisms perform diverse roles on our planet most of which are important to make earth a habitable and sustainable ecosystem. Many properties of microorganisms are being utilized as low input biotechnology to solve various problems related to the environment, food security, nutrition, biodegradation, bioremediation, sustainable agriculture, bioenergy and biofuel, bio-based industries including microbial enzymes/ extremozymes, probiotics etc. The book series covers all the wider aspects and unravels the role of microbes towards achieving a sustainable world. It focuses on various microbial technologies related to sustenance of ecosystems and achieving targets of Sustainable Development Goals. Series brings together content on microbe based technologies for replacing harmful chemicals in agriculture, green alternatives to fossil fuels, use of microorganisms for reclamation of wastelands/ stress affected regions, bioremediation of contaminated habitats, biodegradation purposes. Volumes in the series also focus on the use of microbes for various industrial purposes including enzymes, extremophilic microbes and enzymes, effluent treatment, food products.

The book series is a peer reviewed compendium focused on bringing up contemporary themes related to microbial technology from all parts of the world, at one place for its readers, thereby ascertaining the crucial role of microbes in sustaining the ecosystems.

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Dhanasekaran Dharumadurai • Diana R. Cundell
Editors

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Foreword

Industrial microbiology is an area of applied microbiology that uses microorganisms to produce high-value products such as chemicals, drugs, fuel, and electricity. This field constantly evolves with new techniques and new microbes being recruited to the area as microbiologists discover new possible applications.

The book *Industrial Microbiology-Based Entrepreneurship: Making Money from Microbes* is a carefully crafted text written by experts in the field that provides the reader with an overlook of the techniques used nowadays. Moreover, the book adds details and focuses also on the entrepreneurship angle of industrial microbiology, providing the reader with analysis of the economic impact of the techniques and products developed.

The first chapter is an introduction to the field and explains the scope and application of industrial microbiology, setting the information necessary for the reader to dive in the following chapters.

Following the introduction, the next chapters provide explanations and market analysis of mass production of enzymes, such as xylanase, protease, pectinase, and cellulase.

The book expands past enzymes production, providing insight to diverse topics in industrial microbiology spanning from vaccine productions to biogas.

Chapters 8, 9, 10, 11, 12, and 13 describe different topics and the employment of different microbes in the field, with chapters diving into the following topics:

- Production of chitinase using *Pseudomonas* species.
- Production of agar from *Gelidium.*
- Production of pro-vitamin A, exopolysaccharides, organic acids-citric acid, and organic acids-lactic acid.
- Production of agricultural effective microorganisms and bio-organic liquid fertilizers and plant nutrition enhancer.

Of current interest, Chap. 19 analyzes the costs and provides a business plan for large production of corona vaccines. Other interesting topics discussed in the book are the production of biogas, bio-stimulants, vinegar, and fertilizers.

In summary, *Industrial Microbiology-Based Entrepreneurship: Making Money from Microbes* is full of helpful information including about microbiology and from a marketing point of view. This makes this book a valuable publication for researchers, students, and other readers who are entering the world of industrial microbiology or who want more detailed information on this expanding field.

Best regards,

Manuela Tripepi

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Preface

When the first microbiologists discovered these tiny unicellular organisms in the 1800s, they were associated with disease and illness and it was not until the discovery of antibiotics in the 1920s that this notoriety began to abate. We now understand that microbes are very much "yin and yang," with both positive and negative members. They are both an integral part of our environment and manipulated for over 100 years for human gain to produce foods, remove waste products, and create advanced pharmaceutical products. These tiny entities are appealing to study as they have few needs and, when well chosen, can be grown easily and inexpensively thereby creating many new exciting products to improve lives around the globe. We are also at a point in history where harvesting raw materials from the Earth is beginning to fade and, unless we want our lives to change substantially, there has to be investment in future strategies that promise a very real payoff. So, instead of the classic "what can microbes make" approach, this book has looked at microorganisms from a new standpoint, namely how can they make money for those culturing them! Our three co-editors, Dr. Dharumadurai Dhanasekaran, Dr. Natarajan Amerasan, and myself, Dr. Diana R. Cundell, have together applied their expertise to compile a new type of book that seeks to encourage microbiologists to examine what might be needed rather than just creating a list series of what is already here. This collection of ideas reveals much about those who have edited this book as well as those contributing to it, but the reader should be able to find within something that will stimulate ideas of their own. Compiling these 19 chapters into *Industrial Microbiology-Based Entrepreneurship: Making Money from Microbes* and allowing them to flow easily into one another has allowed for the entrepreneurs included within to run the gamut from as individual enzyme production, which is anticipated to impact processing industries such as food production and biogas production, which could revolutionize fuels, to very general ideas such as biopolymers, food crop protection, and vaccine manufacture.

If we take *just* the latter three and look at them in more detail we can already see why this is a useful book for the microbiologist's library. Biopolymers are becoming big business in biomedical applications where they can enhance wound healing,

blood clotting, and prevent infections. Again, when natural products are used versus synthetic ones they are ultimately less expensive and patients show better recovery and less unwanted effects when exposed to them. Synthesis of biopolymers from microorganisms also has another advantage. When used as packaging material it allows for items that are used naturally by others in the environment and thus are biodegradable. The reader only needs to look at the piles of plastics with their hundreds of years of lifespan on garbage dumps around the globe and that pollute our waters to see the utility of these applications alone. Current estimates are that about up to eight million tons of plastic waste enters our global waters annually, with the majority being plastic packaging. Although many corporations have pledged to become biodegradable, an entrepreneur in this area would be able to significantly reduce both the micro- and macrodebris being produced in this fashion and accelerate the process by which our world is cleaned using natural strategies.

As a planet we cannot continue to maintain an omnivorous diet and must move towards a plant-based one. If this is the case, there will need to be considerable research towards examining methods to reduce the current one-third loss of cultivated crops to microbial disease. Botanists have long suggested that future seed usage should be designed to complement regional needs and insect/microbial infection issues rather than be optimized for productivity. Current countermeasures to crop and seed loss in developed countries have resulted in overuse and resistance to a whole series of insecticides and fungicides. In contrast, the pesticides available in developing countries are many times ineffective or toxic and represent those abandoned by the developed nations. The answer here lies in pitting microbe against microbe, which is in itself an organic solution. Utilizing a more natural approach also allows native ecosystems to persist. As can be seen in this book, those who would produce these new crop biocontrol agents would make money but, and this is more important, it would improve the foods being grown around the world to feed our increasing human populations. Studies have also shown that organic produce is healthier with much higher nutrient levels and antioxidants. Natural microbial products are also much less likely to be something that environmental pests will become resistant to, thus adding to their development appeal.

Using microbes to develop vaccines is another growth area. We have just lived through (and indeed continue to) an era of COVID-19, which was an RNA containing virus that jumped the species barrier into human beings. Why are we seeing this pandemic and will it be the last? The answer is sadly no. Many of the current zoonotic diseases are diluted in their effects on the human population due to carriage by a number of hosts. Studies suggest many of these are likely to be RNA-containing viruses and that rather than adapting to their hosts a series of "waves" or mini epidemics is likely to occur**.** In addition, global climate change is already selecting out the more virulent pathogens, including multi-resistant microbes as well as vectors of zoonotic diseases. This means that developing vaccine strategies that are novel and effective will occur under the extreme pressure we just witnessed with the COVID-19 pandemic and microbes that can be coopted for use in this category will be at a premium.

Realistically although these chapters stimulate the generation of revenue from their discoveries, it can be seen that they will also simultaneously benefit numerous communities around the world. Our society is facing some of the greatest challenges to its integrity due to climate change and population expansion. As this forces us to seek out new strategies in obtaining, packaging, and distributing food and medical care, it is clear that local sourcing of easily produced agents will be necessary. Much of the future can then be considered microbial, with Making Money from Microbes being the first of many explorations into this arena.

Surat, India — Natarajan Amaresan
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About the Series Editor

Naveen Kumar Arora, Fellow of International Society of Environmental Botanists (FISEB), PhD in Microbiology, is Professor and Head of the Department of Environmental Science at Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow, Uttar Pradesh, India. He is a renowned researcher in the field of environmental microbiology and biotechnology. His specific area of research is plant-microbe interactions, particularly plant growth-promoting rhizobacteria. He has more than 75 research articles published in premium international journals and several articles published in magazines and dailies. He is an editor of 25 books, published by Springer. He is a member of several national and international societies, Secretary General of Society for Environmental Sustainability, serves on the editorial board of four journals, and a reviewer of several international journals. He is also the editor in chief of the journal *Environmental Sustainability* published by Springer Nature. He has delivered lectures at conferences and seminars around the globe. He has a long-standing interest in teaching at the PG level and is involved in taking courses in bacteriology, microbial physiology, environmental microbiology, agriculture microbiology, and industrial microbiology. He has been advisor to 134 postgraduate and 11 doctoral students. He has been awarded for excellence in research by several societies and national and international bodies/organizations. Although an academician and researcher by profession, he has a huge obsession for the wildlife and its conservation and has authored a book, *Splendid Wilds*. He is the President of Society for Conservation of Wildlife and has a dedicated website www.naveenarora.co.in for the cause of wildlife and environment conservation.

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Natarajan Amaresan is an Assistant Professor at C.G. Bhakta Institute of Biotechnology, Uka Tarsadia University, Gujarat. He has received his undergraduate, postgraduate, and doctorate degrees in Microbiology. Dr. N. Amaresan has over 16 years of experience in teaching and research in various allied fields of microbiology, mainly microbial ecology, plant-microbe interactions, and others. He has been awarded young scientist awards by Association of Microbiologists of India, National Academy of Biological Sciences, and recipient of visiting scientist fellowship from National Academy of India. He has published more than 60 research articles, 13 books, and 45 book chapters of national and international repute. He has handled various projects sponsored by DBT, DST, GEMI, etc., and guided students for their doctoral and master's degrees.

Dhanasekaran Dharumadurai is working as an Associate Professor, Department of Microbiology, Bharathidasan University, Tiruchirappalli, India. He was awarded UGC-Raman Post-Doctoral Fellowship and worked in the University of New Hampshire, USA. He was awarded Fellow of Linnean Society, London, UK, and INSA Visiting Scientist Fellowship by the National Science Academy. He has graduated 12 PhDs and 76 MScs with over 106 research publications, 49 book chapters, and an H-index of 30 and citations of 2850. He filed two Indian Patents and organized 8 national level seminar, conference, and workshop programs. He has edited 11 books and authored 4 laboratory manuals. His research focus is microbiome profiling of actinorhizal root nodules, lichen, poultry gut, and cattle's reproductive system.

Diana R. Cundell received her PhD in medicine from The Royal Postgraduate Medical Federation, London, U.K. in 1993 and is currently a Professor of Biology and the Pre-Medical Studies Program Director at Jefferson University. Her research spans over 30 years and during the past decade has focused on herbal medicines as antimicrobial and immunomodulatory agents. Dr. Cundell has published research on several phytomedicines including curcumin (turmeric) and their utility in safely managing chronic inflammatory disease. She is the recent author of the book *Allicin, the natural sulfur compound from garlic with many uses* as well as over 60 articles and holds 4 process patents associated with breathing wall systems. Dr. Cundell sits on the Editorial Board of *Plant Biology* and *Phytomedicine* and has acted as a guest editor for *Current Immunology Reviews*.

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Chapter 1
Microbiology-Based Entrepreneurship

Selvaraj Jayaraman, Durairaj Sekar, Ponnulakshmi Rajagopal, Vijayalakshmi Periyasamy, Mani Panangal, and Kumaran Subramanian

Abstract Microbiologists can use entrepreneurial microbiology, a multidisciplinary field that includes the investigation, discovery, and monetisation of living things, food, plants, and biological resources seeing how they could be beneficial to humans, to help address economic issues such as job insufficiency, fundamental, and national developments. According to Eniola (African entrepreneurship: challenges and opportunities for doing business. Springer, 2018), entrepreneurs are mentioned for technology innovation, economic growth, economic success, economic change, and application of possessed competencies. Science is continually being adapted for industrial, domestic, and ecological uses as a fast-evolving subject. With the rapid advancement of these novel aspects of microbiology, a new perspective is required to combine these innovative aspects into economic stability creation and growth. Commercialisation of microbiology and the integration of

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entrepreneurial microbiology in school and university educational plan will transform the way microbiology is viewed and make it among the economy's favourable influences.

Keywords Entrepreneurship · Microbiology · Self-employment · Diagnostics · Industry

1.1 Introduction

Science is an ever-changing, fast-paced subject that is always being changed for industrial, domestic, and ecological reasons. With how quickly these new ideas in microbiology are coming out, a new way of looking at things is needed to make sure that these new ideas can also be used to make money and grow the economy. The country's economy has been in a mess for a long time, with the inflation rate rising and the workforce still being underpaid, even though the government has tried to help. There has been no significant drop in the number of people looking for jobs, even though the government has tried to help. A lot of people are now saying that the entrepreneurial spirit in the country's economy is a great way to get out of the current financial downturn.

Microbiology as a course covers a wide range of topics, including healthcare, pharmaceuticals, and the food business, to mention a few. A microbiologist's job is to study microorganisms, but once the general public hears about controversial topics like the biologic-autistic disorder link, clone research, stem-cell research, and genetically altered foods, an anti-science attitude develops, despite the millions of dollars spent annually on microbial research and analysis, as well as the notable discoveries made daily. Now it is up to these microbiologists to defend themselves and their conclusions in front of the general public. A nation's population is compelled to launch entrepreneurship for economic growth, therefore it should come as no surprise that entrepreneurial microbiology, an intrinsic means of employment creation and invariably a means of predicting open market issues, would be pursued. With the advancements in advanced education and the rapid changes in technological breakthroughs, it is critical to explain to students and lecturers a biological system of biotechnological riches and entrepreneurial revolution (Bell 2010).

1.2 Microbiological Entrepreneurship

Entrepreneurs, according to Eniola (2018), are known for innovation development, economic growth, economic gain, economic transformation, and application of acquired competencies, taking into account their multidisciplinary features. While entrepreneurship microbiology is a multifaceted field that studies, discovers, and commercialises live organisms, foods, plants, and biological resources to see how

they could be helpful to humans (Akinkugbe and Onilude 2013), this is an open door for microbiologists to assist in addressing economic problems such as job scarcity, fundamental, and national developments. The lack of resources, amenities, and the necessary technical skills for recombinant DNA technology stymies innovative research and economic growth initiatives in the country, and has thus proven to be one of the barriers to pursuing entrepreneurial improvements and advancements (Bogoro 2015). This has demonstrated that, in order to counteract the society's ever-increasing rate of unemployment, our educational module must incorporate this entrepreneurial aspect to aid its economic process. Our country is bestowed and recognised with a plethora of scholastic intellectual natural resources and assets that have the potential to boost the economy and reduce the current level of cerebrum depletion. Entrepreneurship entails the ability to see new opportunities and take action to make a difference.

The commercial climate in India is far more favourable to sociologies and much less so to microbiology, which is why microbiology-based research and development struggles to thrive and survive. This can be shown in how microbiology is considered among bioscience courses in schools, universities, and potential workplaces. Those that persevere in the face of adversity and finally achieve do so because they are passionate about the subject or because microbiology is used as a basis for other, seemingly more relevant careers such as medicine and medical laboratory science. In India, the majority of microbiologists work in academia, with just a small number working in the healthcare and food industries, where specialities such as medical laboratory science, medical microbiology, pharmaceutical microbiology, and other related fields are widely desired after. Commoditisation of microbiology and the integration of entrepreneurial microbiology in school and university teaching modules will transform the way microbiology is viewed and make it one of the positive economic influences. By generating a niche of new job opportunities, entrepreneurial microbiology may be a driving force of economic transformation, transforming lives. Its long-term success will be determined firstly by public awareness, perception, knowledge, and acceptance; and, secondarily, an unbiased and cooperative relationship among industries, educational institutions, and investment groups. The United Kingdom's Biotechnology Young Entrepreneur Scheme (Biotechnology YES), for example, teaches students and scholars how to make money from microorganisms through a competition. Most importantly, the plan provides as a platform for students and scholars to gain a better understanding of the procedures involved in bioscience commercialisation (Eniola 2018). The fate of the Indian economy ultimately depends on a new generation of scientific business visionaries who emerge with goals and go out to achieve them, thereby creating economic prosperity and jobs. Diverse contenders in inventive biotechnology are in the scholastics with the assistance of the government or hierarchical financing, it is because stockholders and industries do not have the wherewithal for research, and thus rarely conduct forth new scientific innovations, while educational institutions are unable to underwrite the high value of product development, in as much as financial specialists and companies are more than willing to underwrite the high value of product development. As a result, it is critical

to transfer breakthrough scientific initiatives from educational institutions to businesses once enough scientific data is available to implement a build-out strategy. Nonetheless, the chance that the inventions would fail at the expense of the shareholders cannot be ruled out (Life Science Austria 2017). Protecting scientific entrepreneurial concepts is an important aspect of revolutionary technology that ensures it cannot be easily copied by competitors. Shareholders will want to ensure that a unique product concept does not become obsolete due to imitation (Shimasaki 2009). In other situations, it is also preferable to obtain legal protection through product licencing: particularly in the field of biosciences, timely licencing is frequently a great strategy. There are a variety of ways for biotech businesses and educational laboratories to collaborate in order to reach scientific consensus (Steven and Uma 2014). Because affluent biotech corporations produce biotech products, it is prudent to raise skilled individuals with research-based information that can be transformed into a result of resourceful objectives worthy of commercialisation. Regardless of how brilliant these individuals are at coming up with unique ideas, only a handful of them have the resources required to start a new firm. One solution could be to show their business plan to a financial speculator and acquire loans and subsidies. Investing in pharmaceutical and biotechnology start-ups might come with a lot of risks, but it also comes with the chance of bigger payouts and advantages. Creating scientific recreational grounds within university zones and regions is one way to enliven entrepreneurial activity within the academic community. The goal is to provide a large number of experienced advisers in intellectual property law, project finance, and commercial enterprise to newly founded biotech companies.

1.3 Microbiology's Scope and Importance

Viruses, bacteria, protozoa, and fungi, among other species and agents, are too small to be seen with the human eye in the world around us. A microbiologist is a scientist who studies bacteria that exist in a wide range of environments, including hot springs, the arctic, the human body, and many other living things, as well as the depths of the sea and ocean. Microbiology is thus an important science since bacteria have a harmful and beneficial impact on all aspects of life (Rama 2009). As a result, Prescott et al. (2005) defined microbiology as the study of organisms and agents too small to be seen clearly with the naked eye, that is, it is the study of microorganisms that requires sterilisation and the use of culture media to isolate and cultivate them. Microbiology is divided into two categories: fundamental and applied. Many microbiologists are primarily concerned with the biology of microbes. They are called virologists (viruses), bacteriologists (bacteria), phycologists or algologists (algae), mycologists (fungi), or protozoologists if they specialise in a certain category of microorganisms (protozoa). Others work on topics such as microbial physiology, microbial ecology, microbial cytology, microbial genetics, microbial taxonomy, and molecular biology, and are interested in microbial morphology or specific functional processes. Of course, a person can be viewed from both perspectives (e.g., as a

bacteriologist who works on taxonomic problems). Many microbiologists have a more applied focus and concentrate on real-world issues in sectors including medical microbiology, food and dairy microbiology, and public health microbiology (basic research is also conducted in these fields). Prescott et al. (2005) further highlighted the current career paths of professional microbiologists as follows:

Medical Microbiology This is one of the most significant and active branches of microbiology, and it deals with human and animal diseases. Medical microbiologists discover the infectious disease agent and devise strategies to eradicate or control it. They are frequently involved in the search for novel, unidentified viruses such as the hantavirus, SARS virus, and a variety of others. Microbiologists are also interested in how bacteria cause disease.

Public Health Microbiology Medical microbiology is intimately linked to this. Microbiologists in public health strive to keep contagious diseases from spreading. They frequently inspect neighbourhood food establishments and water sources to ensure that they are safe and clear of infectious disease pathogens.

Immunology Immunologists study how the immune system defends the body against viruses and how infectious agents react. It is also one of the fastest-growing fields in research; for example, monoclonal antibody production and use techniques have advanced at a breakneck pace. Immunology also deals with practical health issues including allergies and autoimmune illnesses like rheumatoid arthritis, as well as their causes and treatments.

Agricultural Microbiology The impact of microorganisms on agriculture is the subject of this study. Agricultural microbiologists research plant diseases that affect vital food crops, develop strategies to improve soil fertility and agricultural yields, and investigate the role of bacteria in the digestive systems of ruminants like cattle. There is currently a lot of interest in employing bacterial and viral insect diseases as pesticide alternatives. Microbiology of Food and Dairy Products: These microbiologists work to prevent food spoiling and the spread of foodborne diseases including botulism and salmonellosis. Microorganisms are also used to manufacture cheese, yoghurts, pickles, and beer. Microorganisms may become a more important food source for cattle and people in the future.

Industrial Microbiology Microorganisms are used by industrial microbiologists to create antibiotics, vaccines, steroids, alcohols and other solvents, vitamins, amino acids, and enzymes. Even low-grade ores can be leached of valuable minerals by microorganisms.

Microbial Ecology This relates to the interactions between microorganisms and their living and non-living environments. Microbial ecologists research how microorganisms contribute to the carbon, nitrogen, and sulphur cycles in soil and freshwater. The study of pollution's impacts on microorganisms is especially essential due to the environmental impact these organisms have. Microorganisms are also used in bioremediation by microbial ecologists to lessen pollution effects.

Microbial Genetics and Molecular Biology The nature of genetic information and how it governs the behaviour of cells and organisms are the focus of these studies. Understanding gene function has been greatly aided by the use of microbes. Microbial geneticists contribute to applied microbiology by developing new microbial strains that are more effective at creating useful products. Substances are tested for their ability to induce cancer using genetic approaches.

Genetic Engineering More recently, work in microbial genetics and molecular biology has spawned the discipline of genetic engineering, which will have a significant impact on microbiology, biology as a whole, and medicine. Engineered microbes are utilised to create valuable items more quickly and efficiently. New genes can now be put into plants and animals; for example, it may be feasible to give corn and wheat a nitrogen-fixing gene, allowing them to grow without nitrogen fertiliser.

1.4 Diagnostics

Clinical laboratory professionals in hospitals, public health laboratories, commercial medical or veterinary diagnostic laboratories, and private companies are diagnostic microbiologists. Patients or animal samples sent in by doctors or veterinarians are tested in hospitals and laboratories. These tests identify the bacterium that is making a patient/animal sick and can aid a doctor's or veterinarian's treatment options by evaluating whether the microbe is sensitive to antimicrobial drugs like antibiotics or resistant to them. Clinical microbiologists track and determine the cause of illness outbreaks in public health laboratories. Clinical microbiologists work in private companies to create new diagnostic tests and treatments. These specialists may supervise a complete clinical laboratory and its employees at higher levels of their careers.

1.5 Biosafety

Biosafety experts ensure that work in clinical and research laboratories is carried out safely, with the proper equipment and procedures, and that all federal, state, and local legislation and recommendations are followed. Their goal is to keep staff safe from injury or infection, as well as to keep germs and other biological agents out of the lab. They accomplish this through teaching researchers and clinical laboratory workers, establishing safety policies and procedures, and providing laboratory design advice. Professionals in the field of biosafety operate in a variety of settings, including colleges and universities, private enterprises, hospitals, and government agencies.

1.6 Hybrid Career Paths

Some microbiologists combine their scientific knowledge with other skills and interests. A bachelor's degree in microbiology is usually required, as well as a degree or additional training in a second subject. Business analysts assist companies and investment organisations in assessing a certain scientific or medical market in order to inform their strategy and judgments. A business analyst with a microbiological background, for example, could assist an investment firm in deciding whether or not to fund a biotechnology venture. Some business analysts work for a corporation directly, while others work for consulting firms or as independent consultants. They often hold a master's degree in business administration (M.B.A.).

Infectious disease physicians and veterinarians receive their training as doctors (M.D. or D.O.) or veterinarians (D.V.M.) before specialising in patient care for people and animals with infectious diseases such as HIV/AIDS, TB, or Q-fever. Infectious disease specialists may treat patients as well as conduct microbiology research.

Patent lawyers work at legal firms or private enterprises. Patents for innovative scientific devices, techniques, or goods are written and filed to safeguard intellectual property. Patent infringement lawsuits are also pursued or defended by them. Patent lawyers have both a law degree (J.D.) and scientific knowledge.

Professionals in public policy and regulatory affairs work for government agencies, non-profit groups, and private businesses. These individuals work in government to create rules, legislation, and regulations pertaining to biomedical products, healthcare, and laboratory research. These experts assist non-profits and private corporations in understanding and advocating for certain rules and regulations.

Science education or outreach specialists work at universities and colleges, non-profit organisations, museums and government agencies. Some also work for private firms' corporate social responsibility departments. These professionals plan and coordinate science-related programmes and events for the general public and K-12 students.

Science writers work for a variety of organisations, including newspapers, periodicals, and other forms of media, as well as government agencies. They also operate as freelancers on a regular basis. They must stay up with current events and new research published in order to study stories and create articles on technical issues.

1.7 Microbiology for Self-Employment and Self-Productivity

The following can be considered in order to re-engineer microbiological courses taught in universities in order to generate graduates capable of self-employment and self-productivity for the country:

1. All students should be required to take an entrepreneurial course as part of their university degree, according to national policy.
2. The entrepreneurship course should never be provided as a general studies education (GSE) subject that all students at a given level must take. Students will regard the course as a significant course in their studies, career development, and preparation for self-employment after graduation as a result of its inclusion as a departmental course.
3. The course tutor in microbiology, for example, should be a microbiologist with entrepreneurship training who can educate students on the fundamentals of entrepreneurship as well as familiarise them with the numerous self-employment prospects accessible in their field of study. The course instructor should also be able to assist students in creating a business of their choice inside their field of study's self-employment options. A professional entrepreneur teacher and a professional in the field of study that relates to the business in question should validate the designed business in order to assess the workability of the business as a small-scale business, the economic cost of the business, the market outlet of the business, the economic gain of the business, and its sustainability. As a result, you may decide whether it is worth putting up or not.
4. When creating a business, students should be required to work in groups of at least five people to avoid repeating business designs, lower the financial cost of starting individual enterprises, and enhance the business's workforce capability.
5. All students in all fields should be required to participate in the student industrial work experience scheme (SIWES). The plan can now be used to achieve two goals. The original goal was to provide students with actual job experience related to their field of study, but now it is being carried out under firms that are running the type of design business of their choice on a huge scale. As a result, students will become familiar with the industry and will be able to learn it practically from professionals in the sector. As a result, the government will save money on the costs of setting up student entrepreneurship centres for hands-on learning, which may not be enough to accommodate the growing number of students, as well as the costs of paying wages to staff at the centres, as is the case presently.
6. Entrepreneurial success stories should be featured in the curriculum, particularly in the student's field of study, to encourage students to develop an interest in self-employment and self-productivity.
7. Students with the greatest business design from each faculty must be recognised at graduation and given a financial reward from the federal government to start their own firm right after graduation. For other graduates, the federal government should establish the Enterprise Bank, which will be tasked with providing loans to students who want to start their own businesses. The bank will also serve as the graduates bank for the business in question, and the loan will be paid with low interest across the board for all businesses based on the capital provided. The Enterprise Bank should also hire a consulting firm to oversee the success and long-term viability of the enterprises it supports. The Enterprise Bank should identify the best business enterprises in each state and grant national recognition

and, if possible, a monetary award by the state government where the businesses are located.

1.8 Conclusion

Medicine, agriculture and food sciences, ecology, genetics, biochemistry, and molecular biology are just a few of the domains where microbiology has a significant impact. As a result, the importance of microbiologists in national development cannot be overstated. This highlights the importance of universities producing microbiologists. However, given the issue of mass student enrolment in universities as well as mass student graduation from universities, as well as the global economic recession, which has resulted in mass graduate unemployment in the country, it is necessary to re-engineer the microbiology taught in our universities in order to achieve the desired motive of education for self-employment.

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Chapter 2
Mass Multiplication, Production Cost Analysis and Marketing of Protease

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Abstract Proteases are widely distributed enzymes that play an important role in both synthesis and breakdown. The catalytic characteristics of proteases have allowed their use in a variety of industrial processes, including detergents, leather, textiles, medicine, feed, and trash. Researchers are exploring numerous techniques to discover, redesign, or artificially manufacture enzymes with improved applicability in industrial processes in response to the expanding demands and applications. Proteases have been successfully used as chemical substitutes and environmentally benign indications for nature and the environment. The most common protease producers are *Bacillus* sp. and *Aspergillus* sp., which are produced via submerged and solid-state fermentation, respectively. Thermostable and solvent-tolerant proteases are important for biotechnological and industrial applications because of their resistance to denaturing agents and chemicals. The current chapter highlights the microbial sources, mass production, existing and future uses of microbial proteases in various sectors, and the estimated costs to assist new entrepreneurs.

Keywords Proteases · Detergent industry · Leather industry · Textiles industry · Entrepreneur

2.1 Introduction

Enzymes are proteins produced by living organisms that catalyse chemical reactions in highly efficient and environmentally favourable ways. All enzymes, which are classified into six types, are essential for survival, and their malfunction causes disease (Homaei 2015). Proteases or proteolytic enzymes can break down peptide bonds in proteins. Proteases are classified as hydrolases in class 3 and peptide hydrolases or peptidases in subclass 3.4, according to the International Union of

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