



# **Nano-Technological Intervention in Agricultural Productivity**

---

**Javid A. Parray • Mohammad Yaseen Mir  
Nowsheen Shameem**

**WILEY**

# Table of Contents

[Cover](#)

[Title Page](#)

[Copyright](#)

[About the Authors](#)

[About the Book](#)

[1 Nanotechnology and Nanoparticles](#)

[1.1 Nanoparticles and Their Functions](#)

[1.2 Classification of NPs](#)

[1.3 Synthesis of Nanoparticles](#)

[1.4 NPs and Characterization](#)

[1.5 Physicochemical Properties of NPs](#)

[1.6 Functions of NPs](#)

[References](#)

[2 Implications of Nanotechnology and Environment](#)

[2.1 Ecotoxicological Implications of Nanoparticles](#)

[2.2 Nanotechnology and Agriculture](#)

[2.3 Risk Assessment Factors and Modulation of Nanomaterials](#)

[References](#)

[3 Nanotechnology and Disease Management](#)

[3.1 Recent Advancements in Plant Nanotechnology](#)

[3.2 Nanotechnology: Role in Plant-Parasitic Control](#)

[3.3 Abiotic Stress-Tolerant Transgenic Crops and Nanotechnology](#)

[3.4 Plant Pathogens and Nanoparticle Biosynthesis](#)

[3.5 Nanomaterial and Plant Protection Against Pests and Pathogens](#)

[3.6 Future Perspectives](#)

[References](#)

[4 Nanotechnology in Agri-Food Production](#)

[4.1 Nanomaterials](#)

[4.2 Nanotechnology and Food Systems: Food Packing](#)

[4.3 Nano-Nutraceuticals](#)

[4.4 Nanotechnological Advancement in Antimicrobial Peptides \(AMPs\)](#)

[4.5 Assessment of Nanotechnology for Enhanced Food Security](#)

[4.6 Future Perspectives](#)

[References](#)

[5 Nanotechnology: Improvement in Agricultural Productivity](#)

[5.1 Nanoparticle Biosynthesis and Use in Agriculture](#)

[5.2 Nanorobots](#)

[5.3 Natural Nanostructures in Food](#)

[References](#)

[6 Lignin Nanoparticles: Synthesis and Application](#)

[6.1 Overview of Lignin Nanoparticles](#)

[6.2 Lignin Nanoparticle Synthesis \(LNPs\)](#)

[6.3 Application of Lignin Nanoparticles \(LNPs\)](#)

[References](#)

[7 Contemporary Application of Nanotechnology in Agriculture](#)

[7.1 Introduction](#)

[7.2 Nanofertilizers](#)

[7.3 Nanocomposites](#)

[7.4 Nanobiosensors](#)

[7.5 Nanopesticides](#)

[7.6 Natural Nanoparticles: Environmental and Health Implications](#)

[7.7 Future Perspective](#)

[References](#)

## [8 Nanotechnology: Advances in Plant and Microbial Science](#)

[8.1 Engineered Nanomaterials and Soil Remediation](#)

[8.2 Fate and Interactions of Nanomaterials in Soil](#)

[8.3 Nanomaterials and Metal Components: Accumulation and Translocation Within Plants](#)

[8.4 Biotransformation of ENPs in Plants](#)

[8.5 Effect of Nanomaterials on Plants](#)

[References](#)

## [9 Food Application and Processing: Nanotechniques and Bioactive Delivery Systems](#)

[9.1 Introduction](#)

[9.2 Phytochemicals and Nanoparticles](#)

[9.3 Bioactive Delivery Systems](#)

[9.4 Toxicity of Biodegradable Nanoparticles](#)

[9.5 Future Perspectives](#)

[References](#)

[Index](#)

[End User License Agreement](#)

# List of Tables

## Chapter 2

[Table 2.1 Nanomaterials and their impacts on plants and soil microbiota.](#)

## Chapter 3

[Table 3.1 Description of bacterial species for the synthesis metallic nanopartic...](#)

[Table 3.2 Description of fungal species used for the synthesis of different meta...](#)

## Chapter 5

[Table 5.1 Example of the size on naturally formed nanoparticles between food pro...](#)

## Chapter 8

[Table 8.1 Phytotoxic effect of nanoparticles on plants.](#)

# List of Illustrations

## Chapter 1

[Figure 1.1 Description of fullerenes or buck balls \(a\)  \$C\_{60}\$  and \(b\)  \$C\_{70}\$ .](#)

[Figure 1.2 The synthetic models of NPs: top-down and bottom-up approach.](#)

[Figure 1.3 Illustration of synthesis of nanoparticles: \(a\) top-down method and...](#)

## Chapter 3

[Figure 3.1 Nanoparticle biosynthesis via intracellular and extracellular metho...](#)

## Chapter 5

[Figure 5.1 Nanorobot 3D design.](#)

## Chapter 7

[Figure 7.1 Schematic representation of the interaction of NPs with pollutants ...](#)

## Chapter 9

[Figure 9.1 Pathway mechanisms for the controlled release of drugs using nanoca...](#)

[Figure 9.2 The Representation of pH-driven nanoencapsulation of phytochemicals...](#)

# **Nano-Technological Intervention in Agricultural Productivity**

***Javid A. Parray***

*Department of Higher Education  
Government Degree College Eidgah  
Srinagar, India*

***Mohammad Yaseen Mir***

*Department of School Education  
University of Kashmir  
Srinagar, India*

***Nowsheen Shameem***

*Department of Environmental Science  
Cluster University Srinagar  
Jammu and Kashmir, India*

**WILEY**

This edition first published 2021

© 2021 John Wiley & Sons Ltd.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Javid A. Parray, Mohammad Yaseen Mir and Nowsheen Shameem to be identified as the author(s) of this work has been asserted in accordance with law.

*Registered Office*

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

*Editorial Office*

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at [www.wiley.com](http://www.wiley.com).

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

*Limit of Liability/Disclaimer of Warranty*

The contents of this work are intended to further general scientific research, understanding, and discussion only and



are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

*Library of Congress Cataloging-in-Publication Data applied  
for*

Hardback ISBN: 9781119714859

Cover Design: Wiley

Cover Image: © xuanhuongho/Shutterstock

## About the Authors



**Dr. Javid A. Parray, PhD**, is an Assistant Professor in the Higher Education Department at the Government Degree College Eidgah, Srinagar, India, where he teaches the subject of environmental science. He has published many research articles in reputable refereed international and

national journals. He had authored books on different themes, including Approaches to Heavy Metal Tolerance in Plants; Sustainable Agriculture: Biotechniques in Plant Biology; and Sustainable Agriculture: Advances in Plant Metabolome and Microbiome, soil bioremediation, climate change and microbes, etc. He was awarded the 'Scientist of the Year Award' by the Indian Academy of Environmental Science for the year 2015 in addition to being awarded with an international travel grant for participating in international conferences. He is currently the editor and reviewer of many reputed journals. He is also the founder of Academy of Ecoscience. Dr. Parray completed a fast-track project entitled 'Molecular characterization and metabolic potential of rhizospheric bacteria from *Arnebia benthamii* across North Western Himalaya' at CORD, University of Kashmir, India. He finished his postdoctoral research associateship on a DBT-funded project entitled 'Tissue culture-based network programme on saffron'. He earned a PhD degree in environmental science with a specialization in plant microbe interactions on the topic 'Evaluating role of rhizospheric bacteria in saffron culture' from the University of Kashmir, India. Dr. Parray is also the subject course coordinator for Environmental Science Approved CEC-Moocs by MHRD, Government of India, New Delhi.



**Dr. Mohammad Yaseen Mir** was working as a senior researcher in Research project funded by Ministry of

Environment, Forest & Climate Change (MoEF & CC), Government of India along with G.B. Pant National Institute of Himalayan Environment & Sustainable Development under National Mission on Himalayan Studies (NMHS) and has recently joined Department of Education J&K as a teacher. He did his M.Phil and Ph.D Programmes from the University of Kashmir. He published many research articles in reputed, referred international and national journals like Springer/Elsevier/Hindwain. He has also authored book Sustainable Agriculture: Biotechniques in Plant Biology with springer.



**Dr. Newsheen Shameem (M.Phil, Ph.D)** is currently working as an Assistant Professor (CL) in the Department of Environmental Science at Cluster University Srinagar, Jammu and Kashmir, India. She did her doctorate (PhD) from the University of Kashmir on nutraceutical value of wild mushrooms growing in Kashmir valley in the year

2017. She has research expertise in microbial biotechnology, plant bioactivity and biotechnology, medicinal chemistry, and plant microbe interactions. She published many research articles in reputed, referred international and national journals such as Springer, Elsevier, and Hindawi. She has also authored many books on themes such as fresh water microbiology, plant biotechniques, advances in plant metabolome and microbiome, and climate changes and microbes. She is also the recipient of the Junior Scientist of the Year award by the International Foundation for Environment & Ecology.



## **About the Book**

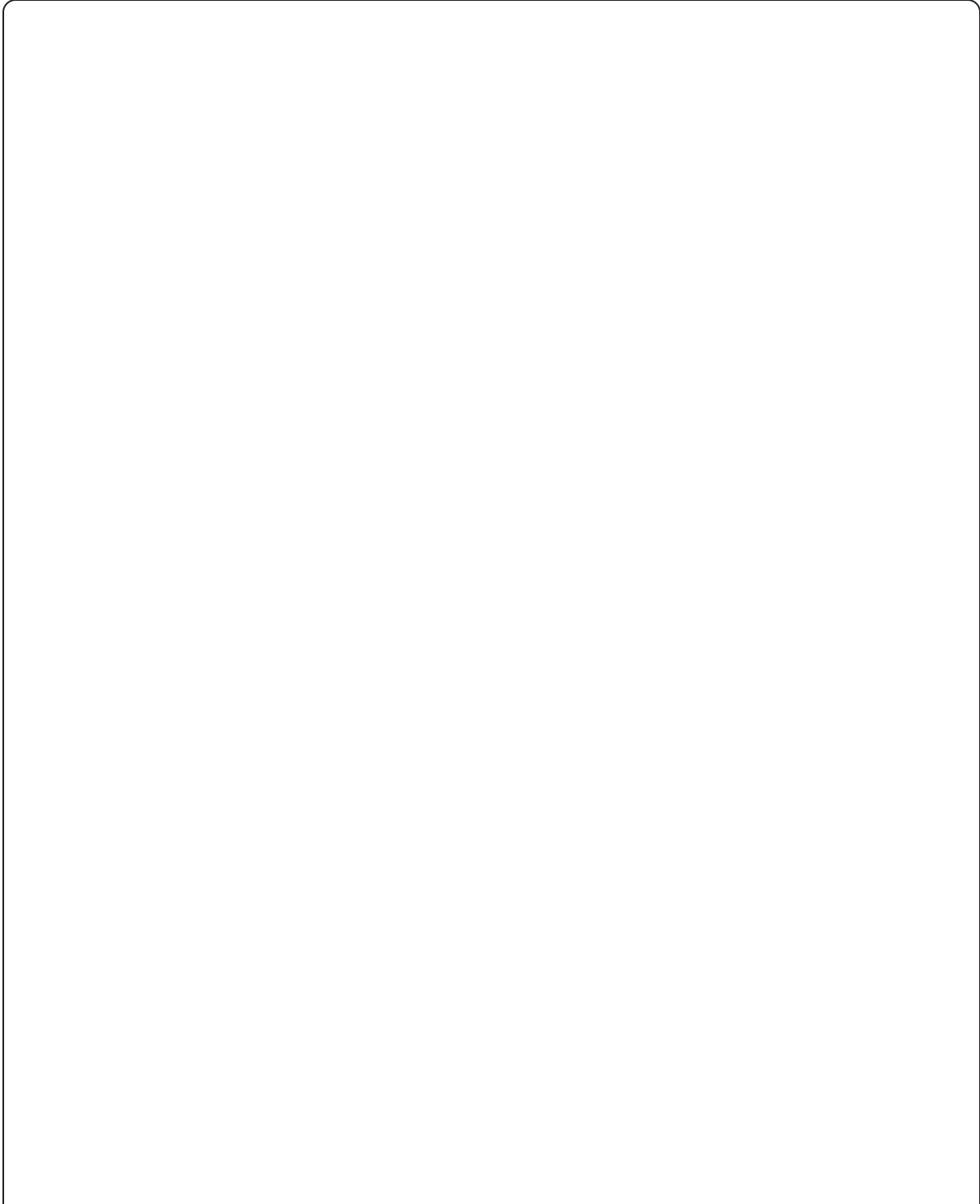
Contemporary agriculture shares the important portion of global economy for any sought-after growth, especially for its major contribution to human upliftment through poverty eradication, fast industrialization, financial change and investment, sustainable resource usage, and environmental management. The miniature aspect of nanotechnology controls major agricultural processes because of its diminutive dimensions. In addition, the use of nanotechnologies can be resonant obstruction, thanks to the many potential advantages such as enhancing the quality and safety of food, decreasing agricultural inputs, and enhancing soil absorption of nanoscale nutrients. This book will be immensely helpful to the students of plant biotechnology, agricultural sciences, and agricultural engineering students of both undergraduate and postgraduate levels in universities, colleges, and research institutes. The book will support researchers who work in the field of plant biotechnology and agricultural sciences. It is hoped this book will be another step towards the beneficial approach in plant biotechnology and setting of a new arena in shaping the new biotechniques towards the sustainable cause.

### **Key features:**

1. Nanotechnological innovations in plant biology
2. Nanotechnology and transgenic via genome editing towards sustainable agricultural systems
3. Nanofertilizers and nanopesticides
4. Nanoparticle protection in plants.

**1**

# **Nanotechnology and Nanoparticles**



# CHAPTER MENU

[Nanoparticles and Their Functions](#)

[Classification of NPs](#)

[Carbon-Based NPs](#)

[Metal Nanoparticles](#)

[Ceramic NPs](#)

[Semiconductor NPs](#)

[Polymeric NPs](#)

[NPs Based on Lipids](#)

[Synthesis of Nanoparticles](#)

[Top-Down Synthesis](#)

[Bottom-Up Synthesis](#)

[NPs and Characterization](#)

[Morphological Characterization](#)

[Structural Characteristics](#)

[Particle Size and Surface Area Characterization](#)

[Optical Characterizations](#)

[Physicochemical Properties of NPs](#)

[Mechanical and Optical Properties](#)

[Magnetic Properties](#)

[Mechanical Properties](#)

[Thermal Properties](#)

[Functions of NPs](#)

[Drugs and Medications](#)

[Materials and Manufacturing](#)

[Environment](#)

[Electronics](#)

[Energy Harvesting](#)

[References](#)

## 1.1 Nanoparticles and Their Functions

Since the past century, nanotechnology has been an advanced research area. RP Feynman coined the term 'nanotechnology' during his famous speech [1]. Nanotechnology developed different types of nanoscale materials. A limited class of one-dimensional materials <100 nm [2] are nanoparticles (NPs). Depending on the form [3], such materials may be 0D, 1D, 2D, or 3D. The importance of these materials showed that the physicochemical properties of a substance, e.g. the optical properties, can be influenced by size. The red wine, yellowish-grey, black, and deep green are the distinctive colours of the 20 nm gold (Au), platinum (Pt), silver (Ag), and palladium (Pd) NPs. These NPs exhibit distinctive colours and properties of various sizes and shapes that can be used in bioimaging applications. [4]. Owing to differences in aspect ratio, nanoshell thickness, and Au concentration, the solution's colour varies. Changing each of the elements mentioned above affects the absorption characteristics of the NPs and is therefore observed in different absorption colours. Usually, NPs consist of three layers: (i) a layer-functionalized surface with several tiny molecules, metal ions, surfactants, and polymers; (ii) a shell layer - a chemically separate core substance; and (iii) a centre - an integral part of the NP and typically refers to

the NP itself [5]. Researchers gained immense interest in multidisciplinary fields because of these exceptional features. NPs may be used for the delivery of drugs [6], chemical and biological sensing [7], gas sensing [8], CO<sub>2</sub> capture [9], and related uses [10].

## 1.2 Classification of NPs

NPs are commonly classified according to morphology, size, and chemical properties in different classes. NPs are classified according to physical and chemical characteristics as follows.

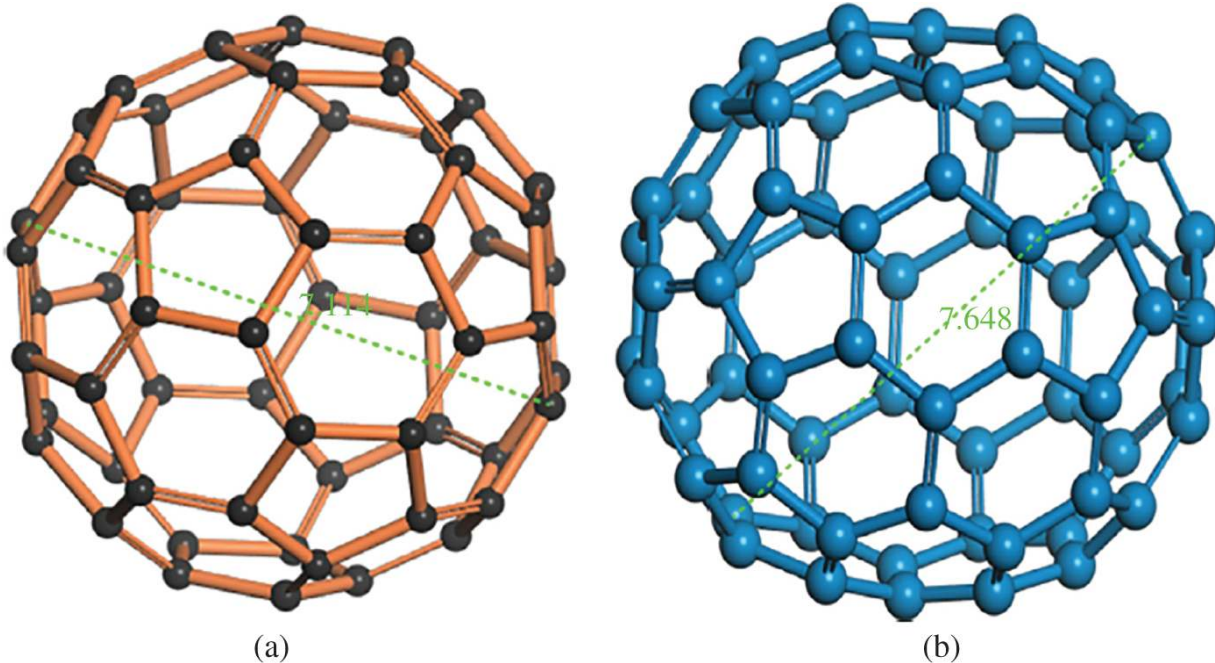
### 1.2.1 Carbon-Based NPs

Two key NP groups based on carbon are fullerenes and carbon nanotubes (CNTs). Fullerenes contain globular hollow cage nanomaterials, similar to allotropic carbon forms. Their electrical conductivity, high power, structure, electron affinity, and flexibility have created considerable commercial interest [11]. Pentagonal and hexagonal C-units were arranged in these materials while each carbon was hybridized. The illustration in [Figure 1.1](#) shows some of the well-known 7.114 and 7.648 nm C<sub>60</sub> and C<sub>70</sub> fullerenes. The long, tubular CNTs have a diameter of 1–2 nm [12]. This can be predicted as metallic or semiconducting based on their helicity diameter [13]. Single, double, or multiple walls may be rolling sheets labelled single-walled nanotubes (SWNTs), double-walled nanotubes (DWNTs), or multi-walled carbon nanotubes (MWNTs), respectively. They are commonly synthesized by carbon precursor deposition, particularly atomic carbons, which are vaporized by a laser or electric arc through metal particles. Recently, they have been synthesized using the chemical vapour deposition (CVD) technique [14]. Because of their specific physical, chemical, and

mechanical characteristics, these materials are widely used in industrial applications, not only in pristine form but also in nanocomposites such as fillers [\[15\]](#), active gas adsorbents for the remediation of the environment [\[16\]](#), and, in general, for various inorganic and organic catalysts [\[17\]](#).

### **1.2.2 Metal Nanoparticles**

Metal NPs comprise metal-made precursors. Because of the well-localized surface plasma resonance (LSPR) characteristics, such NPs have distinct optoelectronic properties. In the visible region of the solar electromagnetic spectrum, the NPs of alkali and noble metals such as Cu, Ag, and Au have broadband absorption. In today's cutting-edge materials, the facet, size, and shape-controlled synthesis of metal NPs are critical [\[4\]](#). Metal NPs are finding applications in many research fields because of their advanced optical properties. The coating of gold NPs is widely used to enhance electronic streaming for scanning electron microscopy (SEM) sampling, thus helping to accomplish good SEM images.



**Figure 1.1** Description of fullerenes or buck balls (a)  $C_{60}$  and (b)  $C_{70}$ .

Source: From Khan et al. [2]. © 2017, Elsevier.

### 1.2.3 Ceramic NPs

NPs from ceramics are inorganic non-metallic solids synthesized by heat and cooling. They are used in amorphous, polycrystalline, solid, porous, or hollow [18] forms. Because of their use in catalysis, photocatalysis, colour photodegradation, and imaging, these NPs offer substantial interest from researchers [19].

### 1.2.4 Semiconductor NPs

Semiconductor materials have properties between metals and non-metals, and because of this property, they find different applications in the literature [20]. Semiconductor NPs have large band gaps, demonstrating significant modifications to their properties with band gap tuning. Items of great significance also include photocatalysis, photo-optics, and electronic devices [21]. Because of their

appropriate band gap and band edge positions, the range of semiconductor NPs is considered exceptionally efficient in water splitting applications [22].

### **1.2.5 Polymeric NPs**

These substances are used for a wide range of commercial applications, such as fillers [15], effective adsorbents of environmental remedial gases [16], and as a support medium for various inorganic and organic calculators because they give specific physical, chemical, and mechanical characteristics [23].

### **1.2.6 NPs Based on Lipids**

In many biomedical applications, they are used, and they contain lipid molecules. Usually, the lipid NP is spherical, 10–1000 nm in diameter. Similar to polymeric NPs, lipid NPs have a solid lipid core and lipophilic molecules within the matrix. The external centre of these NPs has been stabilized by surfactants or emulsifiers [24]. Lipid nanotechnology [25] is a specific field that focuses on the design and synthesis of lipid NPs for various applications, such as drug carriers and delivery [26] and the release of RNA cancer therapy [27].

## **1.3 Synthesis of Nanoparticles**

Various techniques can be used for the synthesis of NPs. Nevertheless, these approaches are generally divided into two main categories, i.e. (i) top-down approach and (ii) bottom-up approach [28, 29] (Figure 1.2). These methods are further divided into different subclasses based on process, reaction state, and adopted protocols.

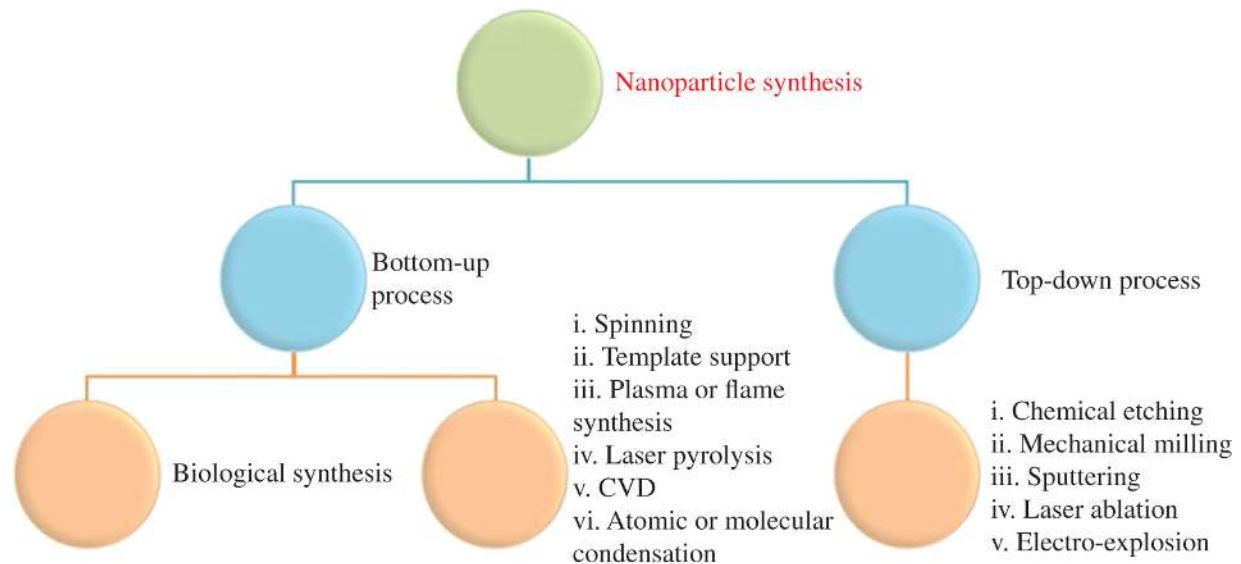
### **1.3.1 Top-Down Synthesis**



The larger molecules are disintegrated into smaller units by a destructive process, and these units are transformed into useful NPs, for example, grinding/milling, CVDs, physical vapour deposition, etc. [29]. This approach is generally used to synthesize NPs from coconut shells (CSs). The milling method is used, whereby raw CS powders were finely milled using ceramic balls and a well-known planetary mill at different time intervals. Via other characterization techniques, the influence of the milling period on the overall size of the NPs is shown.

Furthermore, as time increases, the size of the NP crystallite (Scherrer equation) decreases. In this process, it was also found that the brownish colour faded away with the increment of each hour because of the reduced size of the NPs [30]. Various characterization techniques demonstrated the effect of milling time on the overall size of the NPs. The synthesis of spherical magnetite NPs from natural iron oxide ( $\text{Fe}_2\text{O}_3$ ) ore was shown in the presence of organic oleic acid by a destructive top-down method with a particle size ranging from 20 to 50 nm [31]. To synthesize spherical particles of colloidal carbon using a control scale, a primary top-down route was used. The synthesis technique was based on the continuous chemical adsorption of polyoxometalates on the carbon interfacial surface. Adsorption has transformed black carbon aggregates into relatively smaller spherical particles with a high dispersion capacity and a narrow distribution of size [32]. Microstructures have found that the quantity of carbon particles is lower during the sonication period. Combined grinding and top-down sonication techniques synthesized a sequence of transition metal dichalcogenide nanodots (TMD-NDs) from their crystallites. Every TMD-ND with a size of less than 10 nm shows excellent dispersion and is demonstrated by the narrow distribution of the measure [33]. Highly photoactive  $\text{Co}_3\text{O}_4$  NPs have recently

been produced by top-down laser fragmentation, i.e. a top-down process with an average size of  $5.8 \pm 1.1$  nm. Powerful laser irradiations produce well-uniformed NPs with adequate oxygen vacancy [34].



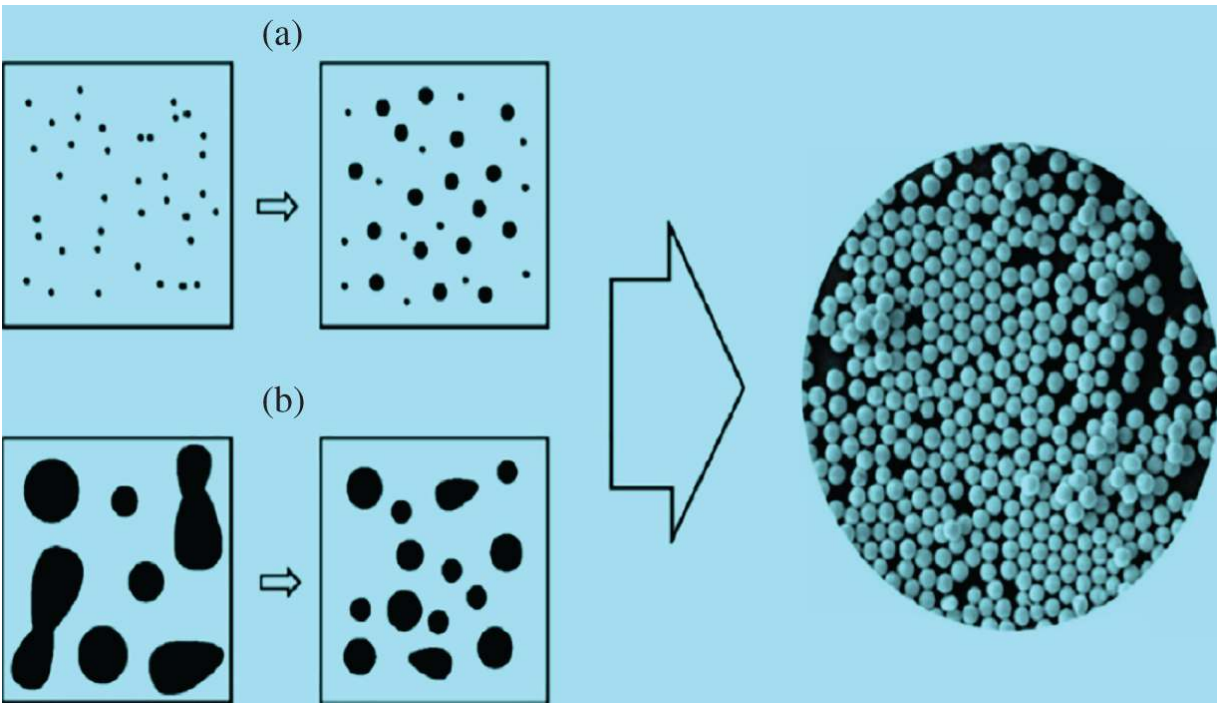
**Figure 1.2** The synthetic models of NPs: top-down and bottom-up approach.

Source: Modified from Iravani [29].

### 1.3.2 Bottom-Up Synthesis

This reverse approach is used to synthesize NPs from relatively more straightforward substances and is also called an approach to building up. Examples include sedimentation and reduction techniques. It encompasses sun-freezing, green synthesis, spinning, and biochemical synthesis [29]. Mogilevsky et al. [35] used this technique to synthesize  $\text{TiO}_2$  anatase NPs to the graphene domains. Alizarin and titanium isopropoxide precursors have been used to synthesize the photoactive composite for methylene blue photocatalytic degradation. The X-ray diffraction (XRD) framework has verified the anatase form [35]. Well-uniform spherical shaped Au nanospheres have been synthesized with monocryalline using top-down laser

irradiation technique [36, 37]. Recently, the solvent exchange method has been used to deliver medical cancer drugs to achieve limited-size low-density lipoprotein (LDL) NPs. The standard approach followed by growth, i.e. up process, is nucleation in this technique. The LDL NPs were obtained without phospholipid use and had high hydrophobicity, which is a prerequisite for drug delivery implementation. [38]. The monodispersed spherical bismuth (Bi) NPs, with top-down and bottom-up approaches, are synthesized with excellent colloidal properties [39]. In bottom-up ethylene glycol, bismuth acetate was melted, although bismuth was converted into a molten state in the top-down process. In boiled diethylene glycol, the molten drop then has been emulsified for NPs. Both methods generated different NPs in size from 100 to 500 nm [39] (Figure 1.3a,b). Green and biogenic bottom-up processing is cost-effective and environmentally sustainable, where biological processes, such as using plant extracts, achieve the synthesis of NPs. For the synthesis of NPs, bacteria, yeast, fungi, *Aloe vera*, tamarind, and even human cells are used. Au-NPs were synthesized from wheat biomass and oat [40] and used as a reduction agent by microorganisms and plant extracts [41, 42]. Figure 1.3 demonstrated the bottom-up (Figure 1.3a) method: decomposing a molecular precursor into simple metal atoms, which transform into colloids and the top-down (Figure 1.3b) method.



**Figure 1.3** Illustration of synthesis of nanoparticles: (a) top-down method and (b) bottom-up method.

Source: From Wang and Xia [39]. © 2004, American Chemical Society.

## 1.4 NPs and Characterization

For the analysis of other physicochemical properties of NPs, different methods of characterization have been used, such as XRD, X-ray photoelectron spectroscopy (XPS), infrared (IR), SEM, transmission electron microscopy (TEM), and Brunauer–Emmett–Teller (BET). Advanced methods are applied for the analysis of the particles.

### 1.4.1 Morphological Characterization

The morphological characteristics of NPs are still of great importance as morphology still affects most of the NP properties. Various characterization techniques exist for morphological research, but microscopic methods exist, such as polarized optical microscopy (POM), SEM, and TEM.

### **1.4.1.1 SEM Technique**

The SEM technique is based on the electron scanning principle and provides all the nanoscale NP data available. This technique is used to study the morphology of their nanomaterials and the dispersion of NPs in the bulk or matrix. This technique [15] showed the distribution of SWNTs in polymer matrix poly(butylene) terephthalate (PBT) and nylon-6. The morphological characteristics of ZnO-modified metal-organic frameworks (MOFs) were studied using the SEM technique, which indicates the dispersion of ZnO-NPs and MOFs' morphologies under different reaction conditions [43].

### **1.4.1.2 TEM Technique**

It is based on the electron transfer principle, so that it can provide descriptions of the bulk content from very low to greater magnification. In addition, it is commonly used for the analysis of different morphologies of the Au-NPs [44]. TEM also provides essential information about two- or more layer materials; the quadruple hollow shell structure of  $\text{Co}_3\text{O}_4$  NPs is observed by TEM, for instance. In Li-ion batteries such as the anode, these NPs have proven themselves to be exceptionally efficient. The porous multi-shell structure induces shorter  $\text{Li}^+$  diffusion path lengths with ample annulled space for buffer volume expansion, good cycling efficiency, higher speed capacity, and essential capacity [45].

## **1.4.2 Structural Characteristics**

The structural characteristics of the structure and function of the bonding materials are of primary importance for studying. It gives details about the bulk properties of the subject material. XRD, energy-dispersive X-ray (EDX) spectroscopy, XPS, IR, Raman spectroscopy, BET, and Zieta

size analyser are the techniques used to study the structural properties of NPs.

#### **1.4.2.1 XRD**

One of the essential characterization techniques is to reveal the structural properties of NPs. The crystalline phase of NPs is provided with sufficient data. It also provides a rough image of the particle size through the Debye-Scherrer [\[8\]](#) formula. In the identification of single and multiphase NP [\[46\]](#) schemes, this approach worked well. However, in smaller NPs with a size smaller than hundreds of atoms, the acquisition and accurate measurement of structural and other parameters may be difficult. Besides, the XRD diffractogram can be affected by NPs with different interatomic lengths having more amorphous characteristics. To obtain accurate data, the diffractograms of bimetallic NPs must be contrasted with those of the corresponding monometallic NPs and their physical mixtures in this case. The best way to make a substantial difference is to measure the simulated bimetallic NP structural model with the spectra of XRD [\[47\]](#) observed.

#### **1.4.2.2 Energy-Dispersive X-ray (EDX)**

To understand the elementary composition with a rough idea of per cent weight, a usually fixed field emission scanning electron microscopy (FE-SEM) or TEM system is commonly used. The electron beam centred on a single NP through SEM or TEM through the software functions to obtain the insight knowledge under observation from the NP. NP consists of constituent elements and, by irradiating electron beams, each of these releases X-ray energy characteristics. The real X-ray intensity is directly proportional to the explicit part of the particle's concentration. Researchers in preparatory materials