INDIA PHYSICAL ENVIRONMENT TEXTBOOK IN GEOGRAPHY FOR CLASS XI Rationalised 2023-24 Rationalised 2023-24 INDIA PHYSICAL ENVIRONMENT TEXTBOOK IN GEOGRAPHY FOR CLASS XI Rationalised 2023-24 First Edition March 2006 Phalguna 1927 Reprinted November 2006 , December 2007, December 2008, January 2010, January 2011, January 2013, January 2014, December 2014, February 2016, February 2017, January 2018, January 2019, January 2020, January 2021, July 2021 and November 2021 Revised Edition February 2022, Phalguna 1944 PD 150T RSP  ` 70.00 Printed on 80 GSM paper with NCERT watermark Published at the Publication Division by the Secretary, National Council of Educational Research and Training, Sri Aurobindo Marg, New Delhi 110 016 and printed at Sita Fine Arts (P.) Ltd., A-16, Naraina Industrial Area, Phase-II, New Delhi - 110 028  Publication Team Head, Publication : Anup Kumar Rajput Division Chief Production : Arun Chitkara Officer Chief Business Manager : Vipin Dewan Chief Editor (In charge) : Bijnan Sutar Editor : R.N. Bhardwaj Production Assistant : Om Prakash Cover Shweta Rao Illustration Dilip Kumar Cartography Cartographic Design Agency OFFICES OF THE PUBLICATION DIVISION, NCERT NCERT Campus Sri Aurobindo Marg New Delhi 110 016 Phone : 011-26562708 108, 100 Feet Road Hosdakere Halli Extension Banashankari III Stage Bengaluru 560 085 Phone : 080-26725740 Navjivan Trust Building P.O.Navjivan Ahmedabad 380 014 Phone : 079-27541446 CWC Campus Opp. Dhankal Bus Stop Panihati Kolkata 700 114 Phone : 033-25530454 CWC Complex Maligaon Guwahati 781 021 Phone : 0361-2674869 ISBN 81-7450-538-5 11094 – INDIA: PHYSICAL ENVIRONMENT Textbook in Geography for Class XI Rationalised 2023-24 FOREWORD The National Curriculum Framework (NCF), 2005, recommends that children's life at school must be linked to their life outside the school. This principle marks a departure from the legacy of bookish learning which continues to shape our system and causes a gap between the school, home and community. The syllabi and textbooks developed on the basis of NCF signify an attempt to implement this basic idea. They also attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas. We hope these measures will take us significantly further in the direction of a child-centred system of education outlined in the National Policy on Education (1986). The success of this effort depends on the steps that school principals and teachers will take to encourage children to reflect on their own learning and to pursue imaginative activities and questions. We must recognise that, given space, time and freedom, children generate new knowledge by engaging with the information passed on to them by adults. Treating the prescribed textbook as the sole basis of examination is one of the key reasons why other resources and sites of learning are ignored. Inculcating creativity and initiative is possible if we perceive and treat children as participants in learning, not as receivers of a fixed body of knowledge. These aims imply considerable change in school routines and mode of functioning. Flexibility in the daily time-table is as necessary as rigour in implementing the annual calendar so that the required number of teaching days are actually devoted to teaching. The methods used for teaching and evaluation will also determine how effective this textbook proves for making children's life at school a happy experience, rather than a source of stress or boredom. Syllabus designers have tried to address the problem of curricular burden by restructuring and reorienting knowledge at different stages with greater consideration for child psychology and the time available for teaching. The textbook attempts to enhance this endeavour by giving higher priority and space to opportunities for contemplation and

wondering, discussion in small groups, and activities requiring hands-on experience. The National Council of Educational Research and Training (NCERT) appreciates the hard work done by the textbook development committee responsible for this book. We wish to thank the Chairperson of the advisory committee for textbooks in Social Sciences, at the higher secondary level, Professor Hari Vasudevan and the Chief Advisor for this book, Professor M.H. Qureshi for guiding the work of this committee. Several teachers contributed to the development of this textbook; we are grateful to their principals for making this possible. We are indebted to the institutions and organisations Rationalised 2023-24 which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairpersonship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution. As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement. Director New Delhi National Council of Educational 20 December 2005 Research and Training vi Rationalised 2023-24 RATIONALISATION OF CONTENT IN THE TEXTBOOKS In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, the NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise. Contents of the textbooks have been rationalised in view of the following: • Overlapping with similar content included in other subject areas in the same class • Similar content included in the lower or higher class in the same subject • Difficulty level • Content, which is easily accessible to students without much interventions from teachers and can be learned by children through self-learning or peerlearning • Content, which is irrelevant in the present context This present edition, is a reformatted version after carrying out the changes given above. Rationalised 2023-24 Rationalised 2023-24 TEXTBOOK DEVELOPMENT COMMITTEE CHAIRPERSON, ADVISORY COMMITTEE FOR TEXTBOOKS IN SOCIAL SCIENCES AT THE HIGHER SECONDARY LEVEL Hari Vasudevan, Professor, Department of History, University of Calcutta, Kolkata CHIEF ADVISOR M. H. Qureshi, Professor, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi MEMBERS Aparna Pandey, Lecturer, DESSH, NCERT, New Delhi Ashok Diwakar, Lecturer, Government P.G College, Sector 9, Gurgaon B. S. Butola, Professor, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi Beena Srikumar, PGT, CRPF Public School, New Delhi Noor Mohammad, Professor, Delhi School of Economics, Delhi University, Delhi MEMBER-COORDINATOR Tannu Malik, Lecturer, DESSH, NCERT, New Delhi Rationalised 2023-24 ACKNOWLEDGEMENTS The National Council of Educational Research and Training acknowledges the contribution of Bhagirathy Jhingran, Teacher, Pathways World School, Gurgaon in the development of this textbook; the National Bureau of Soil Survey and Landuse Planning (under ICAR), Government of India, for providing input for the chapter on Soils. Special thanks are due to Savita Sinha, Professor and Head, Department of Education in Social Sciences and Humanties for her valuable support at every stage of preparation of this textbook. The Council is thankful to the Survey of India for Certification of Maps given in the textbook. It also gratefully acknowledges the support of individuals and organisations as listed below for providing various photographs used in this textbook — M.H. Qureshi, Professor, CSRD, JNU for Figure 5.4 and 5.5; B.S. Butola, Professor, CSRD, JNU for Figure 6.1, 6.5, 6.7 and 6.9; M.V. Srinivasan, Lecturer, DESSH, NCERT for Figure 6.3; ITDC/Ministry of Tourism, Government of India for Figure 2.1, 2.3, 2.8, 2.5, 2.6, 2.7, 2.8, 3.1, 3.3, 4.4, 5.7; Ministry of Environment and Forest, Government of India for Figure 5.1 and 5.6; Social Science Textbook for Class VII, Part II (NCERT, 2005), for Figure 5.3 and Social Science Textbook for Class VIII, Part II (NCERT,

2005), for Figure 2.10. The Council also gratefully acknowledges the contributions of Anil Sharma and Arvind Sharma, DTP Operators; Sameer Khatana and Amar Kumar Prusty, Copy Editors; Bharat Sanwaria, Shreshtha and Deepti Sharma, Proof Readers; Dinesh Kumar, Computer Incharge, who have helped in giving a final shape to this book. The contribution of the Publication Department, NCERT is also duly acknowledged. The following are applicable to all the maps of India used in this book © Government of India, Copyright 2006 1. The responsibility for the correctness of internal details rests with the publisher. 2. The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line. 3. The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh. 4. The interstate boundaries amongst Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the "North-Eastern Areas (Reorganisation) Act.1971," but have yet to be verified. 5. The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India. 6. The State boundaries between Uttaranchal and Uttar Pradesh, Bihar and Jharkhand, and Chhattisgarh and Madhya Pradesh have not been verified by the Governments concerned. 7. The spellings of names in this map, have been taken from various sources. Rationalised 2023-24 CONTENTS FOREWORD v RATIONALISATION OF CONTENT IN THE TEXTBOOKS vii UNIT I : INTRODUCTION 1-6 1. India — Location 2 UNIT II : PHYSIOGRAPHY 7-26 2. Structure and Physiography 8 3. Drainage System 17 UNIT III : CLIMATE AND VEGETATION 27-51 4. Climate 28 5. Natural Vegetation 42 UNIT IV : NATURAL HAZARDS AND DISASTERS: CAUSES, 52-69 CONSEQUENCES AND MANAGEMENT 6. Natural Hazards and Disasters 53 GLOSSARY 70-72 Rationalised 2023-24 CONSTITUTION OF INDIA Part III (Articles 12 – 35) (Subject to certain conditions, some exceptions and reasonable restrictions) guarantees these Fundamental Rights Right to Equality • before law and equal protection of laws; • irrespective of religion, race, caste, sex or place of birth; • of opportunity in public employment; • by abolition of untouchability and titles. Right to Freedom • of expression, assembly, association, movement, residence and profession; • of certain protections in respect of conviction for offences; • of protection of life and personal liberty; • of free and compulsory education for children between the age of six and fourteen years; • of protection against arrest and detention in certain cases. Right against Exploitation • for prohibition of traffic in human beings and forced labour; • for prohibition of employment of children in hazardous jobs. Right to Freedom of Religion • freedom of conscience and free profession, practice and propagation of religion; • freedom to manage religious affairs; • freedom as to payment of taxes for promotion of any particular religion; • freedom as to attendance at religious instruction or religious worship in educational institutions wholly maintained by the State. Cultural and Educational Rights • for protection of interests of minorities to conserve their language, script and culture; • for minorities to establish and administer educational institutions of their choice. Right to Constitutional Remedies • by issuance of directions or orders or writs by the Supreme Court and High Courts for enforcement of these Fundamental Rights. Rationalised 2023-24INTRODUCTION This unit deals with • Location — space relations and India's place in the world UNIT I Rationalised 2023-24 Y ou have already seen the map of India in the previous classes. Now you closely examine the map of India (Figure 1.1). Mark the southernmost and northernmost latitudes and the easternmost and westernmost longitudes. The mainland of India, extends from Kashmir in the north to Kanniyakumari in the south and Arunachal Pradesh in the east to Gujarat in the west. India's territorial limit further extends towards the sea upto 12 nautical miles (about 21.9 km) from the coast. (See the box for conversion). Statute mile = 63,360 inches Nautical mile = 72,960 inches 1 Statute mile = about 1.6 km (1.584 km) 1 Nautical mile = about 1.8 km (1.852 km) Our southern boundary extends upto 6°45' N latitude in the Bay of Bengal. Let us try to analyse the implications of having such a vast longitudinal and latitudinal extent. If you work out the latitudinal and longitudinal extent of India, they are roughly about 30 degrees, whereas the actual distance measured from north to south extremity is 3,214 km, and that from east to west is only 2,933 km.

What is the reason for this difference? Consult Chapter 3 on the topic Latitude, Longitude and Time in the book Practical Work in Geography – Part I (NCERT, 2006) to find out. This difference is based on the fact that the distance between two longitudes decreases towards the poles whereas the distance between two latitudes remains the same everywhere. Find out the distance between two latitudes? From the values of latitude, it is understood that the southern part of the country lies within the tropics and the northern part lies in the sub-tropical zone or the warm temperate zone. This location is responsible for large variations in land forms, climate, soil types and natural vegetation in the country. Now, let us observe the longitudinal extent and its implications on the Indian people. From the values of longitude, it is quite discernible that there is a variation of nearly 30 degrees, which causes a time difference of nearly two hours between the easternmost and the westernmost parts of our country. You are familiar with the concept of Indian Standard Time (IST). What is the use of the standard meridian? While the sun rises in the northeastern states about two hours earlier as compared to Jaisalmer, the watches in Dibrugarh, Imphal in the east and Jaisalmer, Bhopal or Chennai in the other parts of India show the same time. Why does this happen? INDIA – LOCATION CHAPTER There is a general understanding among the countries of the world to select the standard meridian in multiples of 7°30' of longitude. That is why 82°30' E has been selected as the 'standard meridian' of India. Indian Standard Time is ahead of Greenwich Mean Time by 5 hours and 30 minutes. There are some countries where there are more than one standard meridian due to their vast east-to-west extent. For example, the USA has seven time zones. Do you Remember? Rationalised 2023-24 INDIA – LOCATION 3 Figure 1.1 : India : Administrative Divisions Rationalised 2023-24 4 INDIA : PHYSICAL ENVIRONMENT Figure 1.2 : Location of India in the Eastern World Rationalised 2023-24 INDIA – LOCATION 5 Name a few places in India through which the standard meridian passes? India with its area of 3.28 million sq. km accounts for 2.4 per cent of the world's land surface area and stands as the seventh largest country in the world. Find out the names of the countries which are larger than India. SIZE The size of India has endowed her with great physical diversity. Thus, you may appreciate the presence of lofty mountains in the north; large rivers such as Ganga, Brahmaputra, Mahanadi, Krishna, Godavari and Kaveri; green forested hills in northeast and south India; and the vast sandy expanse of Marusthali. You may further appreciate that bounded by the Himalayas in the north, Hindukush and Sulaiman ranges in the northwest, Purvachal hills in the north-east and by the large expanse of the Indian ocean in the south, it forms a great geographic entity known as the Indian subcontinent. It includes the countries — Pakistan, Nepal, Bhutan, Bangladesh and India. The Himalayas, together with other ranges, have acted as a formidable physical barrier in the past. Except for a few mountain passes such as the Khyber, the Bolan, the Shipkila, the Nathula, the Bomdila, etc. it was difficult to cross it. It has contributed towards the evolving of a unique regional identity of the Indian subcontinent. By referring to the physical map of India you can now describe the physical variations which you would come across while travelling from Kashmir to Kanniyakumari and from Jaisalmer in Rajasthan to Imphal in Manipur. Peninsular part of India extends towards the Indian Ocean. This has provided the country with a coastline of 6,100 km in the mainland and 7,517 km in the entire geographical coast of the mainland plus the island groups Andaman and Nicobar located in the Bay of Bengal and the Lakshadweep in the Arabian Sea. Thus India, as a country, is a physically diverse land providing occurrence of varied resources. INDIA AND ITS NEIGHBOURS Examine the location map of India (Figure 1.2). You will notice that India is located in the south-central part of the continent of Asia, bordering the Indian ocean and its two arms extending in the form of Bay of Bengal and the Arabian Sea. This maritime location of Peninsular India has provided links to its neighbouring regions through the sea and air routes. Prepare a list of India's neighbouring countries by consulting the map. Sri Lanka and Maldives are the two island countries located in the Indian Ocean, which are our neighbours. Sri Lanka is separated from India by the Gulf of Mannar and Palk Strait. Differentiate between a Gulf and a Strait.

Do you think that physical barrier is a hindrance in interaction with our neighbouring countries in modern times? Give some examples how we have overcome these difficulties in the present day. Do you Remember? School Bhuvan NCER T is a portal providing map-based learning to bring awareness among the students about country's natural resources, environment and their role in sustainable development. It is an initiative of Bhuvan-NRSC/ISRO, based on NCER T syllabus. You can explore various maps of India on http://bhuvan-app1.nrsc.gov.in/ mhrd_ncert/ Activity: Observe the map of India on an atlas/School Bhuvan NCERT portal and collect information about states/districts/villages located near the international border of India. Rationalised 2023-24 6 INDIA : PHYSICAL ENVIRONMENT 1. Choose the right answer from the four alternatives given below. (i) Which one of the following latitudinal extent is relevant for the extent of India's area? (a) 8°41'N - 35°7'N (c) 8°4'N - 35°6'N (b) 8°4'N - 37°6'N (d) 6°45'N - 37°6'N (ii) Which one of the following countries shares the longest land frontier with India? (a) Bangladesh (c) Pakistan (b) China (d) Myanmar (iii) Which one of the following countries is larger in area than India? (a) China (c) France (b) Egypt (d) Iran (iv) Which one of the following longitudes is the standard meridian for India? (a) 69°30'E (c) 75°30'E (b) 82°30'E (d) 90°30'E 2. Answer the following questions in about 30 words. (i) Does India need to have more than one standard time? If yes, why do you think so? (ii) What are the implications of India having a long coastline? (iii) How is the latitudinal spread of India advantageous to her? (iv) While the sun rises earlier in the east, say Nagaland and also sets earlier, how do the watches at Kohima and New Delhi show the same time? Project/Activity Activity based on Appendix I (Teachers may help in the exercises by explaining and getting it done by the students). (i) On a graph paper, plot the number of districts in Madhya Pradesh, Karnataka, Meghalaya, Goa, Kerala, Haryana. Do the number of districts have some relationship with the area of the state? (ii) Which state amongst Uttar Pradesh, West Bengal, Gujarat, Arunachal Pradesh, Tamil Nadu, Tripura and Rajasthan is the most thickly populated and which one is the least densely populated? (iii) Find out the relationship between the area of the state and the number of districts. (iv) Identify the states with coastal boundaries. (v) Arrange the states from west to east which have only land boundary. Activity based on Appendix II (i) List the Union Territories which have coastal location. (ii) How do you explain the variation in the area and population of NCT Delhi and the Andaman and Nicobar Islands? (iii) On a graph paper, draw a bar diagram to show the area and population of all the Union Territories. EXERCISES Rationalised 2023-24PHYSIOGRAPHY This unit deals with • Structure and Relief; physiographic divisions • Drainage systems: concept of water sheds — the Himalayan and the Peninsular UNIT II Rationalised 2023-24 D o you know that our earth also has a history. The earth and its landforms that we see today have evolved over a very long time. Current estimation shows that the earth is approximately 460 million years old. Over these long years, it has undergone many changes brought about primarily by the endogenic and exogenic forces. These forces have played a significant role in giving shape to various surface and subsurface features of the earth. You have already studied about the Plate Tectonics and the movement of the Earth's plates in the book Fundamentals of Physical Geography (NCERT, 2006). Do you know that the Indian plate was to the south of the equator millions of years ago? Do you also know that it was much larger in size and the Australian plate was a part of it? Over millions of years, this plate broke into many parts and the Australian plate moved towards the southeastern direction and the Indian plate to the north. Can you map different phases in the movement of the Indian plate? This northward movement of the Indian plate is still continuing and it has significant consequences on the physical environment of the Indian subcontinent. Can you name some important consequences of the northward movement of the Indian plate? It is primarily through the interplay of these endogenic and exogenic forces and lateral movements of the plates that the present geological structure and geomorphologic processes active in the Indian subcontinent came into existence. Based on the variations in its geological structure and formations, India can be divided into three geological divisions. These geological regions broadly follow the physical features: (i) The

Penisular Block (ii) The Himalayas and other Peninuslar Mountains (iii) Indo-Ganga-Brahmaputra Plain. THE PENINSULAR BLOCK The northern boundary of the Peninsular Block may be taken as an irregular line running from Kachchh along the western flank of the Aravali Range near Delhi and then roughly parallel to the Yamuna and the Ganga as far as the Rajmahal Hills and the Ganga delta. Apart from these, the Karbi Anglong and the Meghalaya Plateau in the northeast and Rajasthan in the west are also extensions of this block. The northeastern parts are separated by the Malda fault in West Bengal from the Chotanagpur plateau. In Rajasthan, the desert and other desert– like features overlay this block. The Peninsula is formed essentially by a great complex of very ancient gneisses and granites, which constitutes a major part of it. Since the Cambrian period, the Peninsula has been standing like a rigid block with the exception of some of its western coast which is submerged beneath the sea and some other parts changed due to tectonic activity without affecting the original basement. As a part of the Indo-Australian Plate, it has been subjected to various vertical movements and block faulting. The rift valleys of the Narmada, the Tapi and the Mahanadi and the Satpura block STRUCTURE AND PHYSIOGRAPHY CHAPTER Rationalised 2023-24 STRUCTURE AND PHYSIOGRAPHY 9 mountains are some examples of it. The Peninsula mostly consists of relict and residual mountains like the Aravali hills, the Nallamala hills, the Javadi hills, the Veliconda hills, the Palkonda range and the Mahendragiri hills, etc. The river valleys here are shallow with low gradients. You are aware of the method of calculating the gradient as a part of your study of the book Practical Work in Geography– Part I (NCERT, 2006). Can you calculate the gradient of the Himalayan and the Peninsular rivers and draw the comparisons? Most of the east flowing rivers form deltas before entering into the Bay of Bengal. The deltas formed by the Mahanadi, the Krishna, the Kaveri and the Godavari are important examples. THE HIMALAYAS AND OTHER PENINSULAR MOUNTAINS The Himalayas along with other Peninsular mountains are young, weak and flexible in their geological structure unlike the rigid and stable Peninsular Block. Consequently, they are still subjected to the interplay of exogenic and endogenic forces, resulting in the development of faults, folds and thrust plains. These mountains are tectonic in origin, dissected by fast-flowing rivers which are in their youthful stage. Various landforms like gorges, V-shaped valleys, rapids, waterfalls, etc. are indicative of this stage. INDO-GANGA-BRAHMAPUTRA PLAIN The third geological division of India comprises the plains formed by the river Indus, the Ganga and the Brahmaputra. Originally, it was a geo-synclinal depression which attained its maximum development during the third phase of the Himalayan mountain formation approximately about 64 million years ago. Since then, it has been gradually filled by the sediments brought by the Himalayan and Peninsular rivers. Average depth of alluvial deposits in these plains ranges from 1,000-2,000 m. It is evident from the above discussion that there are significant variations among the different regions of India in terms of their geological structure, which has far-reaching impact upon other related aspects. Variations in the physiography and relief are important among these. The relief and physiography of India has been greatly influenced by the geological and geomorphological processes active in the Indian subcontinent. PHYSIOGRAPHY ‘Physiography’ of an area is the outcome of structure, process and the stage of development. The land of India is characterised by great diversity in its physical features. The north has a vast expanse of rugged topography consisting of a series of mountain ranges with varied peaks, beautiful valleys and deep gorges. The south consists of stable table land with highly dissected plateaus, denuded rocks and developed series of scarps. In between these two lies the vast north Indian plain. Based on these macro variations, India can be divided into the following physiographic divisions: (1) The Northern and North-eastern Mountains (2) The Northern Plain Figure 2.1 : A Gorge Rationalised 2023-24 10 INDIA : PHYSICAL ENVIRONMENT Figure 2.2 : India : Physical Rationalised 2023-24 STRUCTURE AND PHYSIOGRAPHY 11 (3) The Peninsular Plateau (4) The Indian Desert (5) The Coastal Plains (6) The Islands. The North and Northeastern Mountains The North and Northeastern Mountains consist of the Himalayas and the Northeastern hills. The Himalayas consist of a series of

parallel mountain ranges. Some of the important ranges are the Greater Himalayan range, which includes the Great Himalayas and the Shiwalik. The general orientation of these ranges is from northwest to the southeast direction in the northwestern part of India. Himalayas in the Darjiling and Sikkim regions lie in an eastwest direction, while in Arunachal Pradesh they are from southwest to the northwest direction. In Nagaland, Manipur and Mizoram, they are in the northsouth direction. The approximate length of the Great Himalayan range, also known as the central axial range, is 2,500 km from east to west, and their width varies between 160-400 km from north to south. It is also evident from the map that the Himalayas stand almost like a strong and long wall between the Indian subcontinent and the Central and East Asian countries. Himalayas are not only the physical barrier, they are also a climatic, drainage and cultural divide. Can you identify the impact of Himalayas on the geoenvironment of the countries of South Asia? Can you find some other examples of similar geoenvironmental divide in the world? The Northern Plains The northern plains are formed by the alluvial deposits brought by the rivers – the Indus, the Ganga and the Brahmaputra. These plains extend approximately 3,200 km from the east to the west. The average width of these plains varies between 150-300 km. The maximum depth of alluvium deposits varies between 1,000-2,000 m. From the north to the south, these can be divided into three major zones: the Bhabar, the Tarai and the alluvial plains. The alluvial plains can be further divided into the Khadar and the Bhangar. Bhabar is a narrow belt ranging between 8-10 km parallel to the Shiwalik foothills at the break-up of the slope. As a result of this, the streams and rivers coming from the mountains deposit heavy materials of rocks and boulders, and at times, disappear in this zone. South of the Bhabar is the Tarai belt, with an approximate width of 10-20 km where most of the streams and rivers re-emerge without having any properly demarcated channel, thereby, creating marshy and swampy conditions known as the Tarai. This has a luxurious growth of natural vegetation and houses a varied wildlife. The south of Tarai is a belt consisting of old and new alluvial deposits known as the Bhangar and Khadar respectively. These plains have characteristic features of mature stage of fluvial erosional and depositional landforms such as sand bars, meanders, oxbow lakes and braided channels. The Brahmaputra plains are known for their riverine islands and sand bars. Most of these areas are subjected to periodic floods Figure 2.3 : The Himalayas Figure 2.4 : Northern Plain Rationalised 2023-24 12 INDIA : PHYSICAL ENVIRONMENT and shifting river courses forming braided streams. The mouths of these mighty rivers also form some of the largest deltas of the world, for example, the famous Sunderbans delta. Otherwise, this is a featureless plain with a general elevation of 50-150 m above the mean sea level. The states of Haryana and Delhi form a water divide between the Indus and the Ganga river systems. As opposed to this, the Brahmaputra river flows from the northeast to the southwest direction before it takes an almost 90° southward turn at Dhubri before it enters into Bangladesh. These river valley plains have a fertile alluvial soil cover which supports a variety of crops like wheat, rice, sugarcane and jute, and hence, supports a large population. The Peninsular Plateau Rising from the height of 150 m above the river plains up to an elevation of 600-900 m is the irregular triangle known as the Peninsular plateau. Delhi ridge in the northwest, (extension of Aravalis), the Rajmahal hills in the east, Gir range in the west and the Cardamom hills in the south constitute the outer extent of the Peninsular plateau. However, an extension of this is also seen in the northeast, in the form of Shillong and Karbi-Anglong plateau. The Peninsular India is made up of a series of patland plateaus such as the Hazaribagh plateau, the Palamu plateau, the Ranchi plateau, the Malwa plateau, the Coimbatore plateau and the Karnataka plateau, etc. This is one of the oldest and the most stable landmass of India. The general elevation of the plateau is from the west to the east, which is also proved by the pattern of the flow of rivers. Name some rivers of the Peninsular plateau which have their confluence in the Bay of Bengal and the Arabian sea and mention some landforms which are typical to the east flowing rivers but are absent in the west flowing rivers. Some of the important physiographic features of this region are tors, block mountains, rift valleys, spurs,

bare rocky structures, series of hummocky hills and wall-like quartzite dykes offering natural sites for water storage. The western and northwestern part of the plateau has an emphatic presence of black soil. This Peninsular plateau has undergone recurrent phases of upliftment and submergence accompanied by crustal faulting and fractures. (The Bhima fault needs special mention, because of its recurrent seismic activities). These spatial variations have brought in elements of diversity in the relief of the Peninsular plateau. The northwestern part of the plateau has a complex relief of ravines and gorges. The ravines of Chambal, Bhind and Morena are some of the well-known examples. On the basis of the prominent relief features, the Peninsular plateau can be divided into three broad groups: (i) The Deccan Plateau (ii) The Central Highlands (iii) The Northeastern Plateau. The Deccan Plateau This is bordered by the Western Ghats in the west, Eastern Ghats in the east and the Satpura, Maikal range and Mahadeo hills in the north. Western Ghats are locally known by different names such as Sahyadri in Maharashtra, Nilgiri hills in Karnataka and Tamil Nadu and Anaimalai hills and Cardamom hills in Kerala. Western Ghats are Figure 2.5 : A Part of Peninsular Plateau Rationalised 2023-24 STRUCTURE AND PHYSIOGRAPHY 13 comparatively higher in elevation and more continuous than the Eastern Ghats. Their average elevation is about 1,500 m with the height increasing from north to south. 'Anaimudi' (2,695 m), the highest peak of Peninsular plateau is located on the Anaimalai hills of the Western Ghats followed by Dodabetta (2,637 m) on the Nilgiri hills. Most of the Peninsular rivers have their origin in the Western Ghats. Eastern Ghats comprising the discontinuous and low hills are highly eroded by the rivers such as the Mahanadi, the Godavari, the Krishna, the Kaveri, etc. Some of the important ranges include the Javadi hills, the Palconda range, the Nallamala hills, the Mahendragiri hills, etc. The Eastern and the Western Ghats meet each other at the Nilgiri hills. The Central Highlands They are bounded to the west by the Aravali range. The Satpura range is formed by a series of scarped plateaus on the south, generally at an elevation varying between 600-900 m above the mean sea level. This forms the northernmost boundary of the Deccan plateau. It is a classic example of the relict mountains which are highly denuded and form discontinuous ranges. The extension of the Peninsular plateau can be seen as far as Jaisalmer in the West, where it has been covered by the longitudinal sand ridges and crescent-shaped sand dunes called barchans. This region has undergone metamorphic processes in its geological history, which can be corroborated by the presence of metamorphic rocks such as marble, slate, gneiss, etc. The general elevation of the Central Highlands ranges between 700-1,000 m above the mean sea level and it slopes towards the north and northeastern directions. Most of the tributaries of the river Yamuna have their origin in the Vindhyan and Kaimur ranges. Banas is the only significant tributary of the river Chambal that originates from the Aravalli in the west. An eastern extension of the Central Highland is formed by the Rajmahal hills, to the south of which lies a large reserve of mineral resources in the Chotanagpur plateau. The Northeastern Plateau In fact it is an extension of the main Peninsular plateau. It is believed that due to the force exerted by the northeastward movement of the Indian plate at the time of the Himalayan origin, a huge fault was created between the Rajmahal hills and the Meghalaya plateau. Later, this depression got filled up by the deposition activity of the numerous rivers. Today, the Meghalaya and Karbi Anglong plateau stand detached from the main Peninsular Block. The Meghalaya plateau is further sub-divided into three: (i) The Garo Hills; (ii) The Khasi Hills; (iii) The Jaintia Hills, named after the tribal groups inhabiting this region. An extension of this is also seen in the Karbi Anglong hills of Assam. Similar to the Chotanagpur plateau, the Meghalaya plateau is also rich in mineral resources like coal, iron ore, sillimanite, limestone and uranium. This area receives maximum rainfall from the south west monsoon. As a result, the Meghalaya plateau has a highly eroded surface. Cherrapunji displays a bare rocky surface devoid of any permanent vegetation cover. The Indian Desert To the northwest of the Aravali hills lies the Great Indian desert. It is a land of undulating topography dotted with longitudinal dunes and barchans. This region receives low rainfall below 150 mm per year; hence, it has arid climate with low vegetation cover. It is because of

these characteristic features that this is also known as Marusthali. It is believed that during the Mesozoic era, this region was under the sea. This can be corroborated by the evidence available at wood fossils park at Aakal and marine deposits around Brahmsar, near Jaisalmer (The approximate age of the wood-fossils is estimated to be 180 million years). Though the underlying rock structure of the desert is an extension of the Peninsular plateau, yet, due to extreme arid conditions, its surface Rationalised 2023-24 14 INDIA : PHYSICAL ENVIRONMENT features have been carved by physical weathering and wind actions. Some of the well pronounced desert land features present here are mushroom rocks, shifting dunes and oasis (mostly in its southern part). On the basis of the orientation, the desert can be divided into two parts: the northern part is sloping towards Sindh and the southern towards the Rann of Kachchh. Most of the rivers in this region are ephemeral. The Luni river flowing in the southern part of the desert is of some significance. Low precipitation and high evaporation makes it a water deficit region. There are some streams which disappear after flowing for some distance and present a typical case of inland drainage by joining a lake or playa. The lakes and the playas have brackish water which is the main source of obtaining salt. The Coastal Plains You have already read that India has a long coastline . On the basis of the location and active geomorphological processes, it can be broadly divided into two: (i) the western coastal plains; (ii) the eastern coastal plains. The western coastal plains are an example of submerged coastal plain. It is believed that the city of Dwaraka which was once a part of the Indian mainland situated along the west coast is submerged under water. Because of this submergence it is a narrow belt and provides natural conditions for the development of ports and harbours. Kandla, Mazagaon, JLN port Navha Sheva, Marmagao, Mangalore, Cochin, etc. are some of the important natural ports located along the west coast. Extending from the Gujarat coast in the north to the Kerala coast in the south, the western coast may be divided into following divisions – the Kachchh and Kathiawar coast in Gujarat, Konkan coast in Maharashtra, Goan coast and Malabar coast in Karnataka and Kerala respectively. The western coastal plains are narrow in the middle and get broader towards north and south. The rivers flowing through this coastal plain do not form any delta. The Malabar coast has got certain distinguishing features in the form of ‘Kayals’ (backwaters), which are used for fishing, inland navigation and also due to its special attraction for tourists. Every year the famous Nehru Trophy Vallamkali (boat race) is held in Punnamada Kayal in Kerala. As compared to the western coastal plain, the eastern coastal plain is broader and is an example of an emergent coast. There are welldeveloped deltas here, formed by the rivers flowing eastward in to the Bay of Bengal. These include the deltas of the Mahanadi, the Godavari, the Krishna and the Kaveri. Because of its emergent nature, it has less number of ports and harbours. The continental shelf extends up to 500 km into the sea, which makes it difficult for the development of good ports and harbours. Name some ports on the eastern coast. Figure 2.6 : The Indian Desert Can you identify the type of sand dunes shown in this picture? Figure 2.7 : Coastal Plains Rationalised 2023-24 STRUCTURE AND PHYSIOGRAPHY 15 The Islands There are two major island groups in India – one in the Bay of Bengal and the other in the Arabian Sea. The Bay of Bengal island groups consist of about 572 islands/islets. These are situated roughly between 6°°N-14°°N and 92°°E -94°°E. The two principal groups of islets include the Ritchie’s archipelago and the Labrynth island. The entire group of island is divided into two broad categories – the Andaman in the north and the Nicobar in the south. They are separated by a waterbody which is called the Ten degree channel. It is believed that these islands are an elevated portion of submarine mountains. However, some smaller islands are volcanic in origin. Barren island, the only active volcano in India is also situated in the Nicobar islands. Some important mountain peaks in Andaman and Nicobar Islands are Saddle peak (North Andaman – 738 m), Mount Diavolo (Middle Andaman – 515 m), Mount Koyob (South Andaman – 460 m) and Mount Thuiller (Great Nicobar – 642 m). The coastal line has some coral deposits, and beautiful beaches. These islands receive convectional rainfall and have an equatorial type of vegetation. On 26 December

2004, the Andaman and Nicobar Islands experienced one of the most devasting natural calamity. Can you name the calamity and identify some other areas which were adversely affected by the same calamity? What was its major consequence? Figure 2.8 : An Island The islands of the Arabian sea include Lakshadweep and Minicoy. These are scattered between 8°°N-12°°N and 71°°E -74°°E longitude. These islands are located at a distance of 280 km-480 km off the Kerala coast. The entire island group is built of coral deposits. There are approximately 36 islands of which 11 are inhabited. Minicoy is the largest island with an area of 453 sq. km. The entire group of islands is broadly divided by the Ten degree channel, north of which is the Amini Island and to the south of the Canannore Island. The Islands of this archipelago have storm beaches consisting of unconsolidated pebbles, shingles, cobbles and boulders on the eastern seaboard. Rationalised 2023-24 16 INDIA : PHYSICAL ENVIRONMENT 1. Choose the right answer from the four alternatives given below. (i) Which one of the water bodies separates the Andaman from the Nicobar? (a) 11°° Channel (c) 10°° Channel (b) Gulf of Mannar (d) Andaman Sea (ii) On which of the following hill range is the 'Dodabeta' peak situated? (a) Nilgiri hills (c) Cardamom hills (b) Anaimalai hills (d) Nallamala hills 2. Answer the following questions in about 30 words. (i) If a person is to travel to Lakshadweep, from which coastal plain does he prefer and why? (ii) Where in India will you find a cold desert? Name some important ranges of this region. (iii) Why is the western coastal plain is devoid of any delta? 3. Answer the following questions in not more than 125 words. (i) Make a comparison of the island groups of the Arabian Sea and the Bay of Bengal. (ii) What are the important geomorphological features found in the river valley plains? (iii) If you move from Badrinath to Sunderbans delta along the course of the river Ganga, what major geomorphological features will you come across? Project/Activity (i) Make a list of major Himalayan peaks from the west to the east with the help of an atlas. (ii) Identify the major landforms of your state and analyse the major economic activity practised by the people in each landform. EXERCISES Rationalised 2023-24Y ou have observed water flowing through the rivers, nalas and even channels during rainy season which drain the excess water. Had these channels not been there, large-scale flooding would have occurred. Wherever channels are ill-defined or choked, flooding is a common phenomenon. The flow of water through well-defined channels is known as 'drainage' and the network of such channels is called a 'drainage system'. The drainage pattern of an area is the outcome of the geological time period, nature and structure of rocks, topography, slope, amount of water flowing and the periodicity of the flow. Do you have a river near your village or city? Have you ever been there for boating or bathing? Is it perennial (always with water) or ephemeral (water during rainy season, and dry, otherwise)? Do you know that rivers flow in the same direction? You have studied about slopes in the other two textbooks of geography (NCERT, 2006) in this class . Can you, then, explain the reason for water flowing from one direction to the other? Why do the rivers originating from the Himalayas in the northern India and the Western Ghat in the southern India flow towards the east and discharge their waters in the Bay of Bengal? A river drains the water collected from a specific area, which is called its 'catchment area'. An area drained by a river and its tributaries is called a drainage basin. The boundary line DRAINAGE SYSTEM CHAPTER Figure 3.1 : A River in the Mountainous Region Important Drainage Patterns (i) The drainage pattern resembling the branches of a tree is known as "dendritic" the examples of which are the rivers of northern plain. (ii) When the rivers originate from a hill and flow in all directions, the drainage pattern is known as 'radial'. The rivers originating from the Amarkantak range present a good example of it. (iii) When the primary tributaries of rivers flow parallel to each other and secondary tributaries join them at right angles, the pattern is known as 'trellis'. (iv) When the rivers discharge their waters from all directions in a lake or depression, the pattern is know as 'centripetal'. Find out some of the patterns in the topo sheet given in Chapter 5 of Practical Work in Geography– Part I (NCERT, 2006). Rationalised 2023-24 18 INDIA : PHYSICAL ENVIRONMENT Figure 3.2 : Major Rivers of India Rationalised 2023-24 DRAINAGE SYSTEM 19 separating one drainage basin from the other is known as the watershed. The

catchments of large rivers are called river basins while those of small rivulets and rills are often referred to as watersheds. There is, however, a slight difference between a river basin and a watershed. Watersheds are small in area while the basins cover larger areas. River basins and watersheds are marked by unity. What happens in one part of the basin or watershed directly affects the other parts and the unit as a whole. That is why, they are accepted as the most appropriate micro, meso or macro planning regions. Indian drainage system may be divided on various bases. On the basis of discharge of water (orientations to the sea), it may be grouped into: (i) the Arabian Sea drainage; and (ii) the Bay of Bengal drainage. They are separated from each other through the Delhi ridge, the Aravalis and the Sahyadris (water divide is shown by a line in Figure 3.1). Nearly 77 per cent of the drainage area consisting of the Ganga, the Brahmaputra, the Mahanadi, the Krishna, etc. is oriented towards the Bay of Bengal while 23 per cent comprising the Indus, the Narmada, the Tapi, the Mahi and the Periyar systems discharge their waters in the Arabian Sea. On the basis of the size of the watershed, the drainage basins of India are grouped into three categories: (i) Major river basins with more than 20,000 sq. km of catchment area. It includes 14 drainage basins such as the Ganga, the Brahmaputra, the Krishna, the Tapi, the Narmada, the Mahi, the Pennar, the Sabarmati, the Barak, etc. (Appendix III). (ii) Medium river basins with catchment area between 2,000-20,000 sq. km incorporating 44 river basins such as the Kalindi, the Periyar, the Meghna, etc. (iii) Minor river basins with catchment area of less than 2,000 sq. km include fairly good number of rivers flowing in the area of low rainfall. If you look at the Figure 3.1 you can see that many rivers have their sources in the Himalayas and discharge their waters either in the Bay of Bengal or in the Arabian Sea. Identify these rivers of North India. Large rivers flowing on the Peninsular plateau have their origin in the Western Ghats and discharge their waters in the Bay of Bengal. Identify these rivers of the South India. The Narmada and Tapi are two large rivers which are exceptions. They along with many small rivers discharge their waters in the Arabian Sea. Name these rivers of the western coastal region from the Konkan to the Malabar coast. On the basis of the mode of origin, nature and characteristics, the Indian drainage may also be classified into the Himalayan drainage and the Peninsular drainage. Although it has the problem of including the Chambal, the Betwa, the Son, etc. which are much older in age and origin than other rivers that have their origin in the Himalayas, it is the most accepted basis of classification. Hence, this scheme has been followed in this book. DRAINAGE SYSTEMS OF INDIA Indian drainage system consists of a large number of small and big rivers. It is the outcome of the evolutionary process of the three major physiographic units and the nature and characteristics of precipitation. THE HIMALAYAN DRAINAGE The Himalayan drainage system has evolved through a long geological history. It mainly includes the Ganga, the Indus and the Brahmaputra river basins. Since these are fed both by melting of snow and precipitation, rivers of this system are perennial. These rivers pass through the giant gorges carved out by the erosional activity carried on simultaneously with the uplift of the Himalayas. Besides deep gorges, these rivers also form V-shaped valleys, rapids and waterfalls in their mountainous Figure 3.3 : Rapids Rationalised 2023-24 20 INDIA : PHYSICAL ENVIRONMENT course. While entering the plains, they form depositional features like flat valleys, ox-bow lakes, flood plains, braided channels, and deltas near the river mouth. In the Himalayan reaches, the course of these rivers is highly tortous, but over the plains they display a strong meandering tendency and shift their courses frequently. River Kosi, also know as the ‘sorrow of Bihar’, has been notorious for frequently changing its course. The Kosi brings huge quantity of sediments from its upper reaches and deposits it in the plains. The course gets blocked, and consequently, the river changes its course. Why does the Kosi river bring such huge quantity of sediments from the upper reaches? Do you think that the discharge of the water in the rivers in general and the Kosi in particular, remains the same, or does it fluctuate? When does the river course receive the maximum quantity of water? What are the positive and negative effects of flooding? EVOLUTION OF THE HIMALAYAN DRAINAGE There are difference of opinion about the

evolution of the Himalayan rivers. However, geologists believe that a mighty river called Shiwalik or Indo-Brahma traversed the entire longitudinal extent of the Himalaya from Assam to Punjab and onwards to Sind, and finally discharged into the Gulf of Sind near lower Punjab during the Miocene period some 5-24 million years ago The remarkable continuity of the Shiwalik and its lacustrine origin and alluvial deposits consisting of sands, silt, clay, boulders and conglomerates support this viewpoint. It is opined that in due course of time Indo– Brahma river was dismembered into three main drainage systems: (i) the Indus and its five tributaries in the western part; (ii) the Ganga and its Himalayan tributaries in the central part; and (iii) the stretch of the Brahmaputra in Assam and its Himalayan tributaries in the eastern part. The dismemberment was probably due to the Pleistocene upheaval in the western Himalayas, including the uplift of the Potwar Plateau (Delhi Ridge), which acted as the water divide between the Indus and Ganga drainage systems. Likewise, the downthrusting of the Malda gap area between the Rajmahal hills and the Meghalaya plateau during the mid-pleistocene period, diverted the Ganga and the Brahmaputra systems to flow towards the Bay of Bengal. THE RIVER SYSTEMS OF THE HIMALAYAN DRAINAGE The Himalayan drainage consists of several river systems but the following are the major river systems: The Indus System It is one of the largest river basins of the world, covering an area of 11,65,000 sq. km (in India it is 321, 289 sq. km and a total length of 2,880 km (in India 1,114 km). The Indus also known as the Sindhu, is the westernmost of the Himalayan rivers in India. It originates from a glacier near Bokhar Chu (31°°15' N latitude and 81°°40' E longitude) in the Tibetan region at an altitude of 4,164 m in the Kailash Mountain range. In Tibet, it is known as ‘Singi Khamban; or Lion’s mouth. After flowing in the northwest direction between the Ladakh and Zaskar ranges, it passes through Ladakh and Baltistan. It cuts across the Ladakh range, forming a spectacular gorge near Gilgit in Jammu and Kashmir. It enters into Pakistan near Chilas in the Dardistan region. Find out the area known as Dardistan. The Indus receives a number of Himalayan tributaries such as the Shyok, the Gilgit, the Zaskar, the Hunza, the Nubra, the Shigar, the Gasting and the Dras. It finally emerges out of the hills near Attock where it receives the Kabul river on its right bank. The other important tributaries joining the right bank of the Indus are the Khurram, the Tochi, the Gomal, the Viboa and the Sangar. They all originate in the Sulaiman ranges. The river flows southward and receives ‘Panjnad’ a little above Mithankot. The Panjnad is the name given to the five rivers of Punjab, namely the Satluj, the Beas, the Ravi, the Chenab and the Jhelum. It finally Rationalised 2023-24 DRAINAGE SYSTEM 21 discharges into the Arabian Sea, east of Karachi. The Indus flows in India only through Jammu and Kashmir. The Jhelum, an important tributary of the Indus, rises from a spring at Verinag situated at the foot of the Pir Panjal in the south-eastern part of the valley of Kashmir. It flows through Srinagar and the Wular lake before entering Pakistan through a deep narrow gorge. It joins the Chenab near Jhang in Pakistan. The Chenab is the largest tributary of the Indus. It is formed by two streams, the Chandra and the Bhaga, which join at Tandi near Keylong in Himachal Pradesh. Hence, it is also known as Chandrabhaga. The river flows for 1,180 km before entering into Pakistan. The Ravi is another important tributary of the Indus. It rises west of the Rohtang pass in the Kullu hills of Himachal Pradesh and flows through the Chamba valley of the state. Before entering Pakistan and joining the Chenab near Sarai Sidhu, it drains the area lying between the southeastern part of the Pir Panjal and the Dhauladhar ranges. The Beas is another important tributary of the Indus, originating from the Beas Kund near the Rohtang Pass at an elevation of 4,000 m above the mean sea level. The river flows through the Kullu valley and forms gorges at Kati and Largi in the Dhaoladhar range. It enters the Punjab plains where it meets the Satluj near Harike. The Satluj originates in the ‘Raksas tal’ near Mansarovar at an altitude of 4,555 m in Tibet where it is known as Langchen Khambab. It flows almost parallel to the Indus for about 400 km before entering India, and comes out of a gorge at Rupar. It passes through the Shipki La on the Himalayan ranges and enters the Punjab plains. It is an antecedent river. It is a very important tributary as it feeds the canal system of the Bhakra Nangal

project. The Ganga System The Ganga is the most important river of India both from the point of view of its basin and cultural significance. It rises in the Gangotri glacier near Gaumukh (3,900 m) in the Uttarkashi district of Uttarakhand. Here, it is known as the Bhagirathi. It cuts through the Central and the Lesser Himalayas in narrow gorges. At Devprayag, the Bhagirathi meets the Alaknanda; hereafter, it is known as the Ganga. The Alaknanda has its source in the Satopanth glacier above Badrinath. The Alaknanda consists of the Dhauli and the Vishnu Ganga which meet at Joshimath or Vishnu Prayag. The other tributaries of Alaknanda such as the Pindar joins it at Karna Prayag while Mandakini or Kali Ganga meets it at Rudra Prayag. The Ganga enters the plains at Haridwar. From here, it flows first to the south, then to the south-east and east before splitting into two distributaries, namely the Bhagirathi and the Padma. The river has a length of 2,525 km. It is shared by Uttarakhand (110 km) and Uttar Pradesh (1,450 km), Bihar (445 km) and West Bengal (520 km). The Ganga basin covers about 8.6 lakh sq. km area in India alone. The Ganga Do you Know? 'Namami Gange Programme', is an Integrated Conservation Mission, approved as "Flagship Programme" by the Union Government in June 2014 with the twin objectives of effective abatement of pollution, conservation and rejuvenation of the National River Ganga. Main pillars of the Namami Gange Programme are: • Sewerage Treatment Infrastructure • River-Front Development • River-Surface Cleaning • Bio-Diversity • Afforestation • Public Awareness • Industrial Effluent Monitoring • Ganga Gram You may explore about this project at http://nmcg.nic.in/NamamiGanga.aspx# Rationalised 2023-24 22 INDIA : PHYSICAL ENVIRONMENT river system is the largest in India having a number of perennial and non-perennial rivers originating in the Himalayas in the north and the Peninsula in the south, respectively. The Son is its major right bank tributary. The important left bank tributaries are the Ramganga, the Gomati, the Ghaghara, the Gandak, the Kosi and the Mahananda. The river finally discharges itself into the Bay of Bengal near the Sagar Island. The Yamuna, the western most and the longest tributary of the Ganga, has its source in the Yamunotri glacier on the western slopes of Banderpunch range (6,316 m). It joins the Ganga at Prayag (Allahabad). It is joined by the Chambal, the Sind, the Betwa and the Ken on its right bank which originates from the Peninsular plateau while the Hindan, the Rind, the Sengar, the Varuna, etc. join it on its left bank. Much of its water feeds the western and eastern Yamuna and the Agra canals for irrigation purposes. Name the states which are drained by the river Yamuna. The Chambal rises near Mhow in the Malwa plateau of Madhya Pradesh and flows northwards through a gorge up wards of Kota in Rajasthan, where the Gandhisagar dam has been constructed. From Kota, it traverses down to Bundi, Sawai Madhopur and Dholpur, and finally joins the Yamuna. The Chambal is famous for its badland topography called the Chambal ravines. The Gandak comprises two streams, namely Kaligandak and Trishulganga. It rises in the Nepal Himalayas between the Dhaulagiri and Mount Everest and drains the central part of Nepal. It enters the Ganga plain in Champaran district of Bihar and joins the Ganga at Sonpur near Patna. The Ghaghara originates in the glaciers of Mapchachungo. After collecting the waters of its tributaries – Tila, Seti and Beri, it comes out of the mountain, cutting a deep gorge at Shishapani. The river Sarda (Kali or Kali Ganga) joins it in the plain before it finally meets the Ganga at Chhapra. The Kosi is an antecedent river with its source to the north of Mount Everest in Tibet, where its main stream Arun rises. After crossing the Central Himalayas in Nepal, it is joined by the Son Kosi from the West and the Tamur Kosi from the east. It forms Sapt Kosi after uniting with the river Arun. The Ramganga is comparatively a small river rising in the Garhwal hills near Gairsain. It changes its course to the southwest direction after crossing the Shiwalik and enters into the plains of Uttar Pradesh near Najibabad. Finally, it joins the Ganga near Kannauj. The Damodar occupies the eastern margins of the Chotanagpur Plateau where it flows through a rift valley and finally joins the Hugli. The Barakar is its main tributary. Once known as the 'sorrow of Bengal', the Damodar has been now tamed by the Damodar Valley corporation, a multipurpose project. The Sarda or Saryu river rises in the Milam glacier in the Nepal Himalayas where it is known as the Goriganga. Along the Indo-Nepal border, it is

called Kali or Chauk, where it joins the Ghaghara. The Mahananda is another important tributary of the Ganga rising in the Darjiling hills. It joins the Ganga as its last left bank tributary in West Bengal. The Son is a large south bank tributary of the Ganga, originating in the Amarkantak plateau. After forming a series of waterfalls at the edge of the plateau, it reaches Arrah, west of Patna, to join the Ganga. The Brahmaputra System The Brahmaputra, one of the largest rivers of the world, has its origin in the Chemayungdung glacier of the Kailash range near the Mansarovar lake. From here, it traverses eastward longitudinally for a distance of nearly 1,200 km in a dry and flat region of southern Tibet, where it is known as the Tsangpo, which means 'the purifier.' The Rango Tsangpo is the major right bank tributary of this river in Tibet. It emerges as a turbulent and dynamic river after carving out a deep gorge in the Central Rationalised 2023-24 DRAINAGE SYSTEM 23 Himalayas near Namcha Barwa (7,755 m). The river emerges from the foothills under the name of Siang or Dihang. It enters India west of Sadiya town in Arunachal Pradesh. Flowing southwest, it receives its main left bank tributaries, viz., Dibang or Sikang and Lohit; thereafter, it is known as the Brahmaputra. The Brahmaputra receives numerous tributaries in its 750 km long journey through the Assam valley. Its major left bank tributaries are the Burhi Dihing and Dhansari (South) whereas the important right bank tributaries are the Subansiri, Kameng, Manas and Sankosh. The Subansiri which has its origin in Tibet, is an antecedent river. The Brahmaputra enters into Bangladesh near Dhubri and flows southward. In Bangladesh, the Tista joins it on its right bank from where the river is known as the Jamuna. It finally merges with the river Padma, which falls in the Bay of Bengal. The Brahmaputra is well-known for floods, channel shifting and bank erosion. This is due to the fact that most of its tributaries are large, and bring large quantity of sediments owing to heavy rainfall in its catchment area. THE PENINSULAR DRAINAGE SYSTEM The Peninsular drainage system is older than the Himalayan one. This is evident from the broad, largely-graded shallow valleys, and the maturity of the rivers. The Western Ghats running close to the western coast act as the water divide between the major Peninsular rivers, discharging their water in the Bay of Bengal and as small rivulets joining the Arabian Sea. Most of the major Peninsular rivers except Narmada and Tapi flow from west to east. The Chambal, the Sind, the Betwa, the Ken, the Son, originating in the northern part of the Peninsula belong to the Ganga river system. The other major river systems of the Peninsular drainage are – the Mahanadi the Godavari, the Krishna and the Kaveri. Peninsular rivers are characterised by fixed course, absence of meanders and nonperennial flow of water. The Narmada and the Tapi which flow through the rift valley are, however, exceptions. The Evolution of Peninsular Drainage System Three major geological events in the distant past have shaped the present drainage systems of Peninsular India: (i) Subsidence of the western flank of the Peninsula leading to its submergence below the sea during the early tertiary period. Generally, it has disturbed the symmetrical plan of the river on either side of the original watershed. (ii) Upheaval of the Himalayas when the northern flank of the Peninsular block was subjected to subsidence and the consequent trough faulting. The Narmada and The Tapi flow in trough faults and fill the original cracks with their detritus materials. Hence, there is a lack of alluvial and deltaic deposits in these rivers. (iii) Slight tilting of the Peninsular block from northwest to the southeastern direction gave orientation to the entire drainage system towards the Bay of Bengal during the same period. River Systems of the Peninsular Drainage There are a large number of river systems in the Peninsular drainage. A brief account of the major Peninsular river systems is given below: The Mahanadi rises near Sihawa in Raipur district of Chhattisgarh and runs through Odisha to discharge its water into the Bay of Bengal. It is 851 km long and its catchment area spreads over 1.42 lakh sq. km. Some navigation is carried on in the lower course of this river. Fifty three per cent of the drainage basin of this river lies in Madhya Pradesh and Chhattisgarh, while 47 per cent lies in Odisha. The Godavari is the largest Peninsular river system. It is also called the Dakshin Ganga. It rises in the Nasik district of Maharashtra and discharges its water into the Bay of Bengal. Its tributaries run through the states of Maharashtra, Madhya Pradesh,

Chhattisgarh, Odisha and Andhra Pradesh. It is 1,465 km long with a catchment area spreading over 3.13 lakh sq. km 49 per cent of this, lies in Maharashtra, 20 per cent in Madhya Pradesh and Chhattisgarh, and the rest in Andhra Pradesh. The Penganga, the Indravati, the Rationalised 2023-24 24 INDIA : PHYSICAL ENVIRONMENT The Tapi is the other important westward flowing river. It originates from Multai in the Betul district of Madhya Pradesh. It is 724 km long and drains an area of 65,145 sq. km. Nearly 79 per cent of its basin lies in Maharashtra, 15 per cent in Madhya Pradesh and the remaining 6 per cent in Gujarat. Luni is the largest river system of Rajasthan, west of Aravali. It originates near Pushkar in two branches, i.e. the Saraswati and the Sabarmati, which join with each other at Govindgarh. From here, the river comes out of Aravali and is known as Luni. It flows towards the west till Telwara and then takes a southwest direction to join the Rann of Kuchchh. The entire river system is ephemeral. EXTENT OF USABILITY OF RIVER WATER The rivers of India carry huge volumes of water per year but it is unevenly distributed both in time and space. There are perennial rivers carrying water throughout the year while the non-perennial rivers have very little water during the dry season. During the rainy season, much of the water is wasted in floods and flows down to the sea. Similarly, when there is a flood in one part of the country, the other area suffers from drought. Why does this happen? Is it the problem of availability of water resource or that of its management? Can you suggest some measures to mitigate the problems of floods and droughts simultaneously occuring in different parts of the country? (See Chapter 6 of the book). Can these problems be solved or minimised by trasfering the surplus water from one basin to the water deficit basins? Do we have some schemes of inter -basin linkage? Teachers may explain the following examples • Periyar Diversion Scheme • Indira Gandhi Canal Project • Kurnool-Cuddapah Canal • Beas-Satluj Link Canal • Ganga-Kaveri Link Canal Pranhita, and the Manjra are its principal tributaries. The Godavari is subjected to heavy floods in its lower reaches to the south of Polavaram, where it forms a picturesque gorge. It is navigable only in the deltaic stretch. The river after Rajamundri splits into several branches forming a large delta. The Krishna is the second largest eastflowing Peninsular river which rises near Mahabaleshwar in Sahyadri. Its total length is 1,401 km. The Koyna, the Tungbhadra and the Bhima are its major tributaries. Of the total catchment area of the Krishna, 27 per cent lies in Maharashtra, 44 per cent in Karnataka and 29 per cent in Andhra Pradesh and Telangana. The Kaveri rises in Brahmagiri hills (1,341m) of Kogadu district in Karnataka. Its length is 800 km and it drains an area of 81,155 sq. km. Since the upper catchment area receives rainfall during the southwest monsoon season (summer) and the lower part during the northeast monsoon season (winter), the river carries water throughout the year with comparatively less fluctuation than the other Peninsular rivers. About 3 per cent of the Kaveri basin falls in Kerala, 41 per cent in Karnataka and 56 per cent in Tamil Nadu. Its important tributaries are the Kabini, the Bhavani and the Amravati. The Narmada originates on the western flank of the Amarkantak plateau at a height of about 1,057 m. Flowing in a rift valley between the Satpura in the south and the Vindhyan range in the north, it forms a picturesque gorge in marble rocks and Dhuandhar waterfall near Jabalpur. After flowing a distance of about 1,312 km, it meets the Arabian sea south of Bharuch, forming a broad 27 km long estuary. Its catchment area is about 98,796 sq. km. The Sardar Sarovar Project has been constructed on this river. Collect information about Narmada river conservation mission named “Namami Devi Narmade” and discuss with your peers. Rationalised 2023-24 DRAINAGE SYSTEM 25 Have you read in the newspapers about the linking of rivers? Do you think that digging a canal is enough to transfer water from the Ganga basin to the Peninsular river? What is the major problem? Consult Chapter 2 of this book and find out the difficulties posed by the unevenness of the terrain. How can the water be lifted from the plain area to the plateau area? Is there sufficient surplus water in the north Indian rivers which can be transferred on a regular basis? Organise a debate on the whole issue and prepare a write up. How do you rank the following problems in using river water? (i) No availability in sufficient quantity (ii) River water pollution (iii) Load of silt in the river water (iv) Uneven seasonal

flow of water (v) River water disputes between states (vi) Shrinking of channels due to the extension of settlements towards the thalweg. Why are the rivers polluted? Have you seen the dirty waters of cities entering into the rivers? Where do the industrial affluents and wastes get disposed of ? Most of the cremation grounds are on the banks of rivers and the dead bodies are sometimes thrown in the rivers. On the occasion of some festivals, the flowers and statues are immersed in the rivers. Large scale bathing and washing of clothes also pollute river waters. How can the rivers be made pollution free? Have you read about Ganga Action Plan, or about a campaign for cleaning the Yamuna at Delhi? Collect materials on schemes for making rivers pollution free and organise the materials in a write up. 1. Choose the right answer from the four alternatives given below. (i) Which one of the following rivers was known as the 'Sorrow of Bengal'? (a) The Gandak (c) The Kosi (b) The Son (d) The Damodar (ii) Which one of the following rivers has the largest river basin in India? (a) The Indus (c) The Ganga (b) The Brahmaputra (d) The Krishna (iii) Which one of the following rivers is not included in 'Panchnad'? (a) The Ravi (c) The Indus (b) The Chenab (d) The Jhelum (iv) Which one of the following rivers flows in a rift valley? (a) The Son (c) The Yamuna (b) The Narmada (d) The Luni (v) Which one of the following is the place of confluence of the Alaknanda and the Bhagirathi? (a) Vishnu Prayag (c) Karan Prayag (b) Rudra Prayag (d) Deva Prayag 2. State the differences between the following. (i) River Basin and Watershed (ii) Dendritic and Trellis drainage pattern (iii) Radial and Centripetal drainage pattern (iv) Delta and Estuary 3. Answer the following questions in about 30 words. (i) What are the socio-economic advantages of inter-linking of rivers in India? EXERCISES Rationalised 2023-24 26 INDIA : PHYSICAL ENVIRONMENT (ii) Write three characterstics of the Peninsular river. 4. Answer the following questions in not more than 125 words. (i) What are the important characteristic features of north Indian rivers? How are these different from Peninsular rivers? (ii) Suppose you are travelling from Haridwar to Siliguri along the foothills of the Himalayas. Name the important rivers you will come across. Describe the characteristics of any one of them. Project/Activity Study the Appendix III and answer the following questions. (i) Which river has the largest proportion of catchment area in the country? (ii) Make a comparative bar diagram on a graph paper to show the length of the courses of the rivers. Rationalised 2023-24CLIMATE AND VEGETATION This unit deals with • Weather and climate – spatial and temporal distribution of temperature, pressure, winds and rainfall; Indian monsoons: mechanism, onset and variability – spatial and temporal; climatic types • Natural vegetation – forest types and distribution; wild life conservation; biosphere reserves UNIT III Rationalised 2023-24 28 INDIA : PHYSICAL ENVIRONMENT W e drink more water during summers. Your uniform during the summer is different from the winters. Why do you wear lighter clothes during summers and heavy woollen clothes during winters in north India? In southern India, woollen clothes are not required. In northeastern states, winters are mild except in the hills. There are variations in weather conditions during different seasons. These changes occur due to the changes in the elements of weather (temperature, pressure, wind direction and velocity, humidity and precipitation, etc.). Weather is the momentary state of the atmosphere while climate refers to the average of the weather conditions over a longer period of time. Weather changes quickly, may be within a day or week but climate changes imperceptively and may be noted after 50 years or even more. You have already studied about the monsoon in your earlier classes. You are also aware of the meaning of the word, "monsoon". Monsoon connotes the climate associated with seasonal reversal in the direction of winds. India has hot monsoonal climate which is the prevalent climate in south and southeast Asia. UNITY AND DIVERSITY IN THE MONSOON CLIMATE The monsoon regime emphasises the unity of India with the rest of southeast Asian region. This view of broad unity of the monsoon type of climate should not, however, lead one to ignore its regional variations which differentiate the weather and climate of different regions of India. For example, the climate of Kerala and Tamil Nadu in the south are so different from that of Uttar Pradesh and Bihar in the north, and yet all of these have a monsoon type of climate. The climate of

India has many regional variations expressed in the pattern of winds, temperature and rainfall, rhythm of seasons and the degree of wetness or dryness. These regional diversities may be described as sub-types of monsoon climate. Let us take a closer look at these regional variations in temperature, winds and rainfall. While in the summer the mercury occasionally touches 55°°C in the western Rajasthan, it drops down to as low as minus 45°°C in winter around Leh. Churu in Rajasthan may record a temperature of 50°°C or more on a June day while the mercury hardly touches 19°°C in Tawang (Arunachal Pradesh) on the same day. On a December night, temperature in Drass (Ladakh) may drop down to minus 45°°C while Thiruvananthapuram or Chennai on the same night records 20°°C or 22°°C. These examples confirm that there are seasonal variations in temperature from place to place and from region to region in India. Not only this, if we take only a single place and record the temperature for just one day, variations are no less striking. In Kerala and in the Andaman Islands, the difference between day and night temperatures may be hardly seven or eight degree Celsius. But in the Thar desert, if the day temperature is around 50°°C, at night, it may drop down considerably upto 15°°-20°°C. CLIMATE CHAPTER Rationalised 2023-24 CLIMATE 29 Now, let us see the regional variations in precipitation. While snowfall occurs in the Himalayas, it only rains over the rest of the country. Similarly, variations are noticeable not only in the type of precipitation but also in its amount. While Cherrapunji and Mawsynram in the Khasi Hills of Meghalaya receive rainfall over 1,080 cm in a year, Jaisalmer in Rajasthan rarely gets more than 9 cm of rainfall during the same period. Tura situated in the Garo Hills of Meghalaya may receive an amount of rainfall in a single day which is equal to 10 years of rainfall at Jaisalmer. While the annual precipitation is less than 10 cm in the northwest Himalayas and the western deserts, it exceeds 400 cm in Meghalaya. The Ganga delta and the coastal plains of Odisha are hit by strong rain-bearing storms almost every third or fifth day in July and August while the Coromandal coast, a thousand km to the south, goes generally dry during these months. Most parts of the country get rainfall during JuneSeptember, but on the coastal areas of Tamil Nadu, it rains in the beginning of the winter season. In spite of these differences and variations, the climate of India is monsoonal in rhythm and character. FACTORS DETERMINING THE CLIMATE OF INDIA India's climate is controlled by a number of factors. Latitude : You already know the latitudinal and longitudinal extent of the land of India. You also know that the Tropic of Cancer passes through the central part of India in east-west direction. Thus, northern part of the India lies in sub-tropical and temperate zone and the part lying south of the Tropic of Cancer falls in the tropical zone. The tropical zone being nearer to the equator, experiences high temperatures throughout the year with small daily and annual range. Area north of the Tropic of Cancer being away from the equator, experiences extreme climate with high daily and annual range of temperature. The Himalayan Mountains : The lofty Himalayas in the north along with its extensions act as an effective climatic divide. The towering mountain chain provides an invincible shield to protect the subcontinent from the cold northern winds. These cold and chilly winds originate near the Arctic circle and blow across central and eastern Asia. The Himalayas also trap the monsoon winds, forcing them to shed their moisture within the subcontinent. Distribution of Land and Water : India is flanked by the Indian Ocean on three sides in the south and girdled by a high and continuous mountain-wall in the north. As compared to the landmass, water heats up or cools down slowly. This differential heating of land and sea creates different air pressure zones in different seasons in and around the Indian subcontinent. Difference in air pressure causes reversal in the direction of monsoon winds. Distance from the Sea : With a long coastline, large coastal areas have an equable climate. Areas in the interior of India are far away from the moderating influence of the sea. Such areas have extremes of climate. That is why, the people of Mumbai and the Konkan coast have hardly any idea of extremes of temperature and the seasonal rhythm of weather. On the other hand, the seasonal contrasts in weather at places in the interior of the country such as Delhi, Kanpur and Amritsar affect the entire sphere of life. Altitude : Temperature decreases with height. Due to thin air,

places in the mountains are cooler than places on the plains. For example, Agra and Darjiling are located on the same latitude, but temperature of January in Agra is 16°°C whereas it is only 4°°C in Darjiling. Relief : The physiography or relief of India also affects the temperature, air pressure, direction and speed of wind and the amount and distribution of rainfall. The windward sides Rationalised 2023-24 30 INDIA : PHYSICAL ENVIRONMENT of Western Ghats and Assam receive high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats. THE NATURE OF INDIAN MONSOON Monsoon is a familiar though a little known climatic phenomenon. Despite the observations spread over centuries, the monsoon continues to puzzle the scientists. Many attempts have been made to discover the exact nature and causation of monsoon, but so far, no single theory has been able to explain the monsoon fully. A real breakthrough has come recently when it was studied at the global rather than at regional level. Systematic studies of the causes of rainfall in the South Asian region help to understand the causes and salient features of the monsoon, particularly some of its important aspects, such as: (i) The onset of the monsoon. (ii) Break in the monsoon. Onset of the Monsoon Towards the end of the nineteenth century, it was believed that the differential heating of land and sea during the summer months is the mechanism which sets the stage for the monsoon winds to drift towards the subcontinent. During April and May when the sun shines vertically over the Tropic of Cancer, the large landmass in the north of Indian ocean gets intensely heated. This causes the formation of an intense low pressure in the northwestern part of the subcontinent. Since the pressure in the Indian Ocean in the south of the landmass is high as water gets heated slowly, the low pressure cell attracts the southeast trades across the Equator. These conditions help in the northward shift in the position of the ITCZ. The southwest monsoon may thus, be seen as a continuation of the southeast trades deflected towards the Indian subcontinent after crossing the Equator. These winds cross the Equator between 40°°E and 60°°E longitudes. Inter Tropical Convergence Zone (ITCZ) The Inter Tropical Convergence Zone (ITCZ) is a low pressure zone located at the equator where trade winds converge, and so, it is a zone where air tends to ascend. In July, the ITCZ is located around 20°N-25°N latitudes (over the Gangetic plain), sometimes called the monsoon trough. This monsoon trough encourages the development of thermal low over north and northwest India. Due to the shift of ITCZ, the trade winds of the southern hemisphere cross the equator between 40° and 60°E longitudes and start blowing from southwest to northeast due to the Coriolis force. It becomes southwest monsoon. In winter, the ITCZ moves southward, and so the reversal of winds from northeast to south and southwest, takes place. They are called northeast monsoons. Figure 4.1 : Onset of Monsoon Inter Tropical Convergence Zone (ITCZ) The Inter Tropical Convergence Zone (ITCZ) is a low pressure zone located at the equator where trade winds converge, and so, it is a zone where air tends to ascend. In July, the ITCZ is located around 20°°N-25°°N latitudes (over the Gangetic plain), sometimes called the monsoon trough. This monsoon trough encourages the development of thermal low over north and northwest India. Due to the shift of ITCZ, the trade winds of the southern hemisphere cross the equator between 40°° and 60°°E longitudes and start blowing from southwest to northeast due to the Coriolis force. It becomes southwest monsoon. In winter, the ITCZ moves southward, and so the reversal of winds from northeast to south and southwest, takes place. They are called northeast monsoons. Rationalised 2023-24 CLIMATE 31 The shift in the position of the ITCZ is also related to the phenomenon of the withdrawal of the westerly jet stream from its position over the north Indian plain, south of the Himalayas. The easterly jet stream sets in along 15°°N latitude only after the western jet stream has withdrawn itself from the region. This easterly jet stream is held responsible for the burst of the monsoon in India. Entry of Monsoon into India : The southwest monsoon sets in over the Kerala coast by 1st June and moves swiftly to reach Mumbai and Kolkata between 10th and 13th June. By mid-July, southwest monsoon engulfs the entire subcontinent (Figure 4.2) Break in the Monsoon During the south-west monsoon period after having rains for a few days, if rain fails to

occur for one or more weeks, it is known as break in the monsoon. These dry spells are quite common during the rainy season. These breaks in the different regions are due to different reasons: (i) In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region. (ii) Over the west coast the dry spells are associated with days when winds blow parallel to the coast. THE RHYTHM OF SEASONS The climatic conditions of India can best be described in terms of an annual cycle of seasons. The meteorologists recognise the following four seasons : (i) the cold weather season (ii) the hot weather season (iii) the southwest monsoon season (iv) the retreating monsoon season. The Cold Weather Season Temperature : Usually, the cold weather season sets in by mid-November in northern India. December and January are the coldest months in the northern plain. The mean daily temperature remains below 21°°C over most parts of northern India. The night temperature may be quite low, sometimes going below freezing point in Punjab and Rajasthan. There are three main reasons for the excessive cold in north India during this season : (i) States like Punjab, Haryana and Rajasthan being far away from the moderating influence of sea experience continental climate. (ii) The snowfall in the nearby Himalayan ranges creates cold wave situation; and (iii) Around February, the cold winds coming from the Caspian Sea and Turkmenistan EI-Nino and the Indian Monsoon EI-Nino is a complex weather system that appears once every three to seven years, bringing drought, floods and other weather extremes to different parts of the world. The system involves oceanic and atmospheric phenomena with the appearance of warm currents off the coast of Peru in the Eastern Pacific and affects weather in many places including India. EI-Nino is merely an extension of the warm equatorial current which gets replaced temporarily by cold Peruvian current or Humbolt current (locate these currents in your atlas). This current increases the temperature of water on the Peruvian coast by 10°°C. This results in: (i) the distortion of equatorial atmospheric circulation; (ii) irregularities in the evaporation of sea water; (iii) reduction in the amount of planktons which further reduces the number of fish in the sea. The word EI-Nino means ‘Child Christ’ because this current appears around Christmas in December. December is a summer month in Peru (Southern Hemisphere). EI-Nino is used in India for forecasting long range monsoon rainfall. In 1990-91, there was a wild EI-Nino event and the onset of southwest monsoon was delayed over most parts of the country ranging from five to twelve days. Rationalised 2023-24 32 INDIA : PHYSICAL ENVIRONMENT Figure 4.2 : India : Normal Dates of Onset of the Southwest Monsoon Rationalised 2023-24 CLIMATE 33 bring cold wave along with frost and fog over the northwestern parts of India. Understanding the Monsoon Attempts have been made to understand the nature and mechanism of the monsoon on the basis of data collected on land, oceans and in the upper atmosphere. The intensity of southwest monsoon winds of southern oscillation can be measured, among others, by measuring the difference in pressure between Tahiti (roughly 20°°S and 140°°W) in French Polynesia in East Pacific and port Darwin (12°°30'S and 131°°E) in northern Australia. Indian Meteorological Department (IMD) can forecast the possible behaviour of monsoons on the basis of 16 indicators. Due to low pressure gradient, the light winds with a low velocity of about 3-5 km per hour begin to blow outwards. By and large, the topography of the region influences the wind direction. They are westerly or northwesterly down the Ganga Valley. They become northerly in the Ganga-Brahmaputra delta. Free from the influence of topography, they are clearly northeasterly over the Bay of Bengal. During the winters, the weather in India is pleasant. The pleasant weather conditions, however, at intervals, get disturbed by shallow cyclonic depressions originating over the east Mediterranean Sea and travelling eastwards across West Asia, Iran, Afghanistan and Pakistan before they reach the northwestern parts of India. On their way, the moisture content gets augmented from the Caspian Sea in the north and the Persian Gulf in the south. What is the role of Westerly Jet Streams in steering these depressions in India? Rainfall : Winter monsoons do not cause rainfall as they move from land to the sea. It is because firstly, they have little humidity; and secondly, due to anti cyclonic circulation on land, the

possibility of rainfall from them reduces. So, most parts of India do not have rainfall in the winter season. However, there are some exceptions to it: (i) In northwestern India, some weak temperate cyclones from the Mediterranean sea cause rainfall in Punjab, Haryana, Delhi and western Uttar Pradesh. Although the amount is meagre, it is highly beneficial for rabi crops. The precipitation is in the form of snowfall in the lower Himalayas. It is this snow that sustains the flow of water in the Himalayan rivers during the summer months. The precipitation goes on decreasing from west to east in the plains and from north to south in the mountains. The average winter rainfall in Delhi is around 53 mm. In Punjab and Bihar, rainfall remains The Peninsular region of India, however, does not have any well-defined cold weather season. There is hardly any seasonal change in the distribution pattern of the temperature in coastal areas because of moderating influence of the sea and the proximity to equator. For example, the mean maximum temperature for January at Thiruvanantapuram is as high as 21°°C, and for June, it is 29.5°°C. Temperatures at the hills of Western Ghats remain comparatively low. Pressure and Winds : By the end of December (22nd December), the sun shines vertically over the Tropic of Capricorn in the southern hemisphere. The weather in this season is characterised by feeble high pressure conditions over the northern plain. In south India, the air pressure is slightly lower. The isobars of 1019 mb and 1013 mb pass through northwest India and far south, respectively. As a result, winds start blowing from northwestern high pressure zone to the low air pressure zone over the Indian Ocean in the south. Rationalised 2023-24 34 INDIA : PHYSICAL ENVIRONMENT south rather it increases from the coast to the interior. The mean daily minimum temperature during the summer months also remains quite high and rarely goes below 26°°C. Pressure and Winds : The summer months are a period of excessive heat and falling air pressure in the northern half of the country. Because of the heating of the subcontinent, the ITCZ moves northwards occupying a position centred at 25°°N in July. Roughly, this elongated low pressure monsoon trough extends over the Thar desert in the north-west to Patna and Chotanagpur plateau in the east-southeast. The location of the ITCZ attracts a surface circulation of the winds which are southwesterly on the west coast as well as along the coast of West Bengal and Bangladesh. They are easterly or southeasterly over north Bengal and Bihar. It has been discussed earlier that these currents of southwesterly monsoon are in reality ‘displaced’ equatorial easterlies. The influx of these winds by mid-June brings about a change in the weather towards the rainy season. In the heart of the ITCZ in the northwest, the dry and hot winds known as ‘Loo’, blow in the afternoon, and very often, they continue to well into midnight. Dust storms in the evening are very common during May in Punjab, Haryana, Eastern Rajasthan and Uttar Pradesh. These temporary storms bring a welcome respite from the oppressing heat since they bring with them light rains and a pleasant cool breeze. Occasionally, the moisture-laden winds are attracted towards the periphery of the trough. A sudden contact between dry and moist air masses gives rise to local storms of great intensity. These local storms are associated with violent winds, torrential rains and even hailstorms. between 25 mm and 18 mm respectively. (ii) Central parts of India and northern parts of southern Peninsula also get winter rainfall occasionally. (iii) Arunachal Pradesh and Assam in the northeastern parts of India also have rains between 25 mm and 50 mm during these winter months. (iv) During October and November, northeast monsoon while crossing over the Bay of Bengal, picks up moisture and causes torrential rainfall over the Tamil Nadu coast, southern Andhra Pradesh, southeast Karnataka and southeast Kerala. The Hot Weather Season Temperature: With the apparent northward movement of the sun towards the Tropic of Cancer in March, temperatures start rising in north India. April, May and June are the months of summer in north India. In most parts of India, temperatures recorded are between 30°-32°°C. In March, the highest day temperature of about 38°°C occurs in the Deccan Plateau while in April, temperature ranging between 38°°C and 43°°C are found in Gujarat and Madhya Pradesh. In May, the heat belt moves further north, and in the north-western part of India, temperatures around 48°°C are not uncommon. The hot weather season in south India is mild and not so intense as found in

north India. The Peninsular situation of south India with moderating effect of the oceans keeps the temperatures lower than that prevailing in north India. So, temperatures remain between 26°°C and 32°°C. Due to altitude, the temperatures in the hills of Western Ghats remain below 25°°C. In the coastal regions, the north-south extent of isotherms parallel to the coast confirms that temperature does not decrease from north to Rationalised 2023-24 CLIMATE 35 Some Famous Local Storms of Hot Weather Season (i) Mango Shower : Towards the end of summer, there are pre-monsoon showers which are a common phenomena in Kerala and coastal areas of Karnataka. Locally, they are known as mango showers since they help in the early ripening of mangoes. (ii) Blossom Shower : With this shower, coffee flowers blossom in Kerala and nearby areas. (iii) Nor Westers : These are dreaded evening thunderstorms in Bengal and Assam. Their notorious nature can be understood from the local nomenclature of 'Kalbaisakhi', a calamity of the month of Baisakh. These showers are useful for tea, jute and rice cultivation. In Assam, these storms are known as "Bardoisila". (iv) Loo : Hot, dry and oppressing winds blowing in the Northern plains from Punjab to Bihar with higher intensity between Delhi and Patna. THE SOUTHWEST MONSOON SEASON As a result of rapid increase of temperature in May over the northwestern plains, the low pressure conditions over there get further intensified. By early June, they are powerful enough to attract the trade winds of Southern Hemisphere coming from the Indian Ocean. These southeast trade winds cross the equator and enter the Bay of Bengal and the Arabian Sea, only to be caught up in the air circulation over India. Passing over the equatorial warm currents, they bring with them moisture in abundance. After crossing the equator, they follow a southwesterly direction. That is why they are known as southwest monsoons. The rain in the southwest monsoon season begins rather abruptly. One result of the first rain is that it brings down the temperature substantially. This sudden onset of the moisture-laden winds associated with violent thunder and lightening, is often termed as the "break" or "burst" of the monsoons. The monsoon may burst in the first week of June in the coastal areas of Kerala, Karnataka, Goa and Maharashtra while in the interior parts of the country, it may be delayed to the first week of July. The day temperature registers a decline of 5°°C to 8°°C between midJune and mid-July. As these winds approach the land, their southwesterly direction is modified by the relief and thermal low pressure over the northwest India. The monsoon approaches the landmass in two branches: (i) The Arabian Sea branch (ii) The Bay of Bengal branch. Monsoon Winds of the Arabian Sea The monsoon winds originating over the Arabian Sea further split into three branches: (i) Its one branch is obstructed by the Western Ghats. These winds climb the slopes of the Western Ghats from 900-1200 m. Soon, they become cool, and as a result, the windward side of the Sahyadris and Western Coastal Plain receive very heavy rainfall ranging between 250 cm and 400 cm. After crossing the Western Ghats, these winds descend and get heated up. This reduces humidity in the winds. As a result, these winds cause little rainfall east of the Western Ghats. This region of low rainfall is known as the rain-shadow area. Find out the rainfall at Kozhikode, Mangalore, Pune and Bengaluru and note the difference. (ii) Another branch of the Arabian sea monsoon strikes the coast north of Mumbai. Moving along the Narmada and Tapi river valleys, these winds cause rainfall in extensive areas of central India. The Chotanagpur plateau gets 15 cm rainfall from this part of the branch. Thereafter, they enter the Ganga plains and mingle with the Bay of Bengal branch. (iii) A third branch of this monsoon wind strikes the Saurashtra Peninsula and the Kachchh. It then passes over west Rationalised 2023-24 36 INDIA : PHYSICAL ENVIRONMENT Figure 4.3 : India : Seasonal Rainfall (June-September) Rationalised 2023-24 CLIMATE 37 Rajasthan and along the Aravalis, causing only a scanty rainfall. In Punjab and Haryana, it too joins the Bay of Bengal branch. These two branches, reinforced by each other, cause rains in the western Himalayas, Monsoon Winds of the Bay of Bengal The Bay of Bengal branch strikes the coast of Myanmar and part of southeast Bangladesh. But the Arakan Hills along the coast of Myanmar deflect a big portion of this branch towards the Indian subcontinent. The monsoon, therefore, enters West Bengal and Bangladesh from south and southeast instead of from the south-

westerly direction. From here, this branch splits into two under the influence of the Himalayas and the thermal low is northwest India. Its one branch moves westward along the Ganga plains reaching as far as the Punjab plains. The other branch moves up the Brahmaputra valley in the north and the northeast, causing widespread rains. Its sub-branch strikes the Garo and Khasi hills of Meghalaya. Mawsynram, located on the crest of Khasi hills, receives the highest average annual rainfall in the world. Here it is important to know why the Tamil Nadu coast remains dry during this season. There are two factors responsible for it: (i) The Tamil Nadu coast is situated parallel to the Bay of Bengal branch of southwest monsoon. (ii) It lies in the rainshadow area of the Arabian Sea branch of the south-west monsoon. Season of Retreating Monsoon The months of October and November are known for retreating monsoons. By the end of September, the southwest monsoon becomes weak as the low pressure trough of the Ganga plain starts moving southward in response to the southward march of the sun. The monsoon retreats from the western Rajasthan by the first week of September. It withdraws from Rajasthan, Gujarat, Western Ganga plain and the Central Highlands by the end of the month. By the beginning of October, the low pressure covers northern parts of the Bay of Bengal and by early November, it moves over Karnataka and Tamil Nadu. By the middle of December, the centre of low pressure is completely removed from the Peninsula. The retreating southwest monsoon season is marked by clear skies and rise in temperature. The land is still moist. Owing to the conditions of high temperature and humidity, the weather becomes rather oppressive. This is commonly known as the 'October heat'. In the second half of October, the mercury begins to fall rapidly, particularly in northern India. The weather in the retreating monsoon is dry in north India but it is associated with rain in the eastern part of the Peninsula. Here, October and November are the rainiest months of the year. The widespread rain in this season is associated with the passage of cyclonic depressions which originate over the Andaman Sea and manage to cross the eastern coast of the southern Peninsula. These tropical cyclones are very destructive. The thickly populated deltas of the Godavari, Krishna and Kaveri are their preferred targets. Every year cyclones bring disaster here. A few cyclonic storms also strike the coast of West Bengal, Bangladesh and Myanmar. A bulk of the rainfall of the Coromondal coast is derived from these depressions and cyclones. Such cyclonic storms are less frequent in the Arabian Sea. TRADITIONAL INDIAN SEASONS In the Indian tradition, a year is divided into six two-monthly seasons. This cycle of seasons, which the common people in north and central India follow is based on their practical experience and age-old perception of weather phenomena. However, this system does not match with the seasons of south India where there is little variation in the seasons. Rationalised 2023-24 38 INDIA : PHYSICAL ENVIRONMENT Seasons Months Months (According to the (According to the Indian Calendar) Gregorian Calendar) Vasanta Chaitra-Vaisakha March-April Grishma Jyaistha-Asadha May-June Varsha Sravana-Bhadra July-August Sharada Asvina-Kartika September-October Hemanta Margashirsa-Pausa November-December Shishira Magha-Phalguna January-February Distribution of Rainfall The average annual rainfall in India is about 125 cm, but it has great spatial variations . Areas of High Rainfall : The highest rainfall occurs along the west coast, on the Western Ghats, as well as in the sub-Himalayan areas is the northeast and the hills of Meghalaya. Here the rainfall exceeds 200 cm. In some parts of Khasi and Jaintia hills, the rainfall exceeds 1,000 cm. In the Brahmaputra valley and the adjoining hills, the rainfall is less then 200 cm. Areas of Medium Rainfall : Rainfall between 100-200 cm is received in the southern parts of Gujarat, east Tamil Nadu, northeastern Peninsula covering Odisha, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur. Areas of Low Rainfall : Western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat and Deccan Plateau receive rainfall between 50-100 cm. Areas of Inadequate Rainfall: Parts of the Peninsula, especially in Andhra Pradesh, Karnataka and Maharashtra, Ladakh and most of western Rajasthan receive rainfall below 50 cm. Snowfall is restricted to the Himalayan region. Identify the pattern of rainfall after consulting the rainfall map.

Monsoons and the Economic Life in India (i) Monsoon is that axis around which revolves the entire agricultural cycle of India. It is because about 64 per cent people of India depend on agriculture for their livelihood and agriculture itself is based on southwest monsoon. (ii) Except Himalayas all the parts of the country have temperature above the threashold level to grow the crops or plants throughout the year.. (iii) Regional variations in monsoon climate help in growing various types of crops. (iv) Variability of rainfall brings droughts or floods every year in some parts of the country. (v) Agricultural prosperity of India depends very much on timely and adequately distributed rainfall. If it fails, agriculture is adversely affected particularly in those regions where means of irrigation are not developed. (vi) Sudden monsoon burst creates problem of soil erosion over large areas in India. (vii) Winter rainfall by temperate cyclones in north India is highly beneficial for rabi crops. (viii) Regional climatic variation in India is reflected in the vast variety of food, clothes and house types. GLOBAL WARMING You know that change is the law of nature. Climate has also witnessed change in the past at the global as well as at local levels. It is changing even now but the change is imperceptible. A number of geological evidences suggest that once upon a time, large part of the earth was under ice cover. Now you might have read or heard the debate on global warming. Besides the natural causes, human activities such as large scale industrialisation and presence of polluting gas in the atmosphere are also important factors responsible for global warming. You might have heard about the “green house effect” while discussing global warming. The temperature of the world is significantly increasing. Carbon dioxide produced by human activities is a major source of concern. This gas, released to the atmosphere in large quantities by burning of fossil fuel, is increasing gradually. Other gases like methane, chlorofluorocarbons, and nitrous oxide which are present in much smaller concentrations in the atmosphere, together with carbon dioxide are known as Rationalised 2023-24 CLIMATE 39 Figure 4.4 : India : Annual Rainfall Rationalised 2023-24 40 INDIA : PHYSICAL ENVIRONMENT changes: one of these is a rise in sea level, as a result of melting of glaciers and sea-ice due to warming. According to the current prediction, on an average, the sea level will rise 48 cm by the end of twenty first century. This would increase the incidence of annual flooding. Climatic change would promote insect-borne diseases like malaria, and lead to shift in climatic boundaries, making some regions wetter and others drier. Agricultural pattern would shift and human population as well as the ecosystem would experience change. What would happen to the Indian sea coasts if the sea level rises 50 cm above the present one? green house gases. These gases are better absorbers of long wave radiations than carbon dioxide, and so, are more effective at enhancing the green house effect. These gases have been contributing to global warming. It is said that due to global warming the polar ice caps and mountain glaciers would melt and the amount of water in the oceans would increase. The mean annual surface temperature of the earth in the past 150 years has increased. It is projected that by the year 2,100, global temperature will increase by about 2° C. This rise in temperature will cause many other 1. Choose the right answer from the four alternatives given below. (i) What causes rainfall on the coastal areas of Tamil Nadu in the beginning of winters? (a) South-West monsoon (c) North-Eastern monsoon (b) Temperate cyclones (d) Local air circulation (ii) What is the proportion of area of India which receives annual rainfall less than 75 cm? (a) Half (c) Two-third (b) One-third (d) Three-fourth (iii) Which one of the following is not a fact regarding South India? (a) Diurnal range of temperature is less here. (b) Annual range of temperature is less here. (c) Temperatures here are high throughout the year. (d) Extreme climatic conditions are found here. (iv) Which one of the following phenomenon happens when the sun shines vertically over the Tropic of Capricorn in the southern hemisphere? (a) High pressure develops over North-western India due to low temperatures. (b) Low pressure develops over North-western India due to high temperatures. (c) No changes in temperature and pressure occur in north-western India. (d) ‘Loo’ blows in the North-western India. EXERCISES Rationalised 2023-24 CLIMATE 41 2. Answer the following questions in about 30 words. (i) What is the Inter-Tropical Convergene Zone? (ii) What is meant by ‘bursting of

monsoon'? Name the place of India which gets the highest rainfall. (iii) Which type(s) of cyclones cause rainfall in north-western India during winter? Where do they originate? 3. Answer the following questions in not more than 125 words. (i) Notwithstanding the broad climatic unity, the climate of India has many regional variations. Elaborate this statement giving suitable examples. (ii) How many distinct seasons are found in India as per the Indian Meteorological Department? Discuss the weather conditions associated with any one season in detail. Project/Activity On the outline map of India, show the following: (i) Areas of winter rain (ii) Wind direction during the summer season (iii) Areas having less than 15°°C temperature in January (iv) Isohyte of 100 cm. Rationalised 2023-24H ave you ever been to a forest for a picnic? You might have surely gone to a park if you live in a city or to a mango, guava or coconut orchard, if you live in a village. How do you differentiate between the natural vegetation and the planted vegetation? The same variety may be found growing wild in the forest under natural conditions and the same tree may be the planted one in your garden under human supervision. Natural vegetation refers to a plant community that has been left undisturbed over a long time, so as to allow its individual species to adjust themselves to climate and soil conditions as fully as possible. India is a land of great variety of natural vegetation. Himalayan heights are marked with temperate vegetation; the Western Ghats and the Andaman Nicobar Islands have tropical rain forests, the deltaic regions have tropical forests and mangroves; the desert and semi desert areas of Rajasthan are known for cactii, a wide variety of bushes and thorny vegetation. Depending upon the variations in the climate and the soil, the vegetation of India changes from one region to another. On the basis of certain common features such as predominant vegetation type and climatic regions, Indian forests can be divided into the following groups: TYPES OF FORESTS (i) Tropical Evergreen and Semi Evergreen forests (ii) Tropical Deciduous forests (iii) Tropical Thorn forests (iv) Montane forests (v) Littoral and Swamp forests. Tropical Evergreen and Semi Evergreen Forests These forests are found in the western slope of the Western Ghats, hills of the northeastern region and the Andaman and Nicobar Islands. They are found in warm and humid areas with an annual precipitation of over 200 cm and mean annual temperature above 22oC. Tropical evergreen forests are well stratified, with layers closer to the ground and are covered with shrubs and creepers, with short structured trees followed by tall variety of trees. In these forests, trees reach great heights up to 60 m or above. There is no definite time for trees to shed their leaves, flowering and fruition. As such these forests appear green all the year round. Species found in these forests include rosewood, mahogony, aini, ebony, etc. The semi evergreen forests are found in the less rainy parts of these regions. Such forests have a mixture of evergreen and moist deciduous trees. The undergrowing climbers provide an evergreen character to these forests. Main species are white cedar, hollock and kail. NATURAL VEGETATION CHAPTER Figure 5.1 : Evergreen Forest Rationalised 2023-24 NATURAL VEGETATION 43 Figure 5.2 : Natural Vegetation Rationalised 2023-24 44 INDIA : PHYSICAL ENVIRONMENT The British were aware of the economic value of the forests in India, hence, large scale exploitation of these forests was started. The structure of forests was also changed. The oak forests in Garhwal and Kumaon were replaced by pine (chirs) which was needed to lay railway lines. Forests were also cleared for introducing plantations of tea, rubber and coffee. The British also used timber for construction activities as it acts as an insulator of heat. The protectional use of forests was, thus, replaced by commercial use. Tropical Deciduous Forests These are the most widespread forests in India. They are also called the monsoon forests. They spread over regions which receive rainfall between 70-200 cm. On the basis of the availability of water, these forests are further divided into moist and dry deciduous. The Moist deciduous forests are more pronounced in the regions which record rainfall between 100-200 cm. These forests are found in the northeastern states along the foothills of Himalayas, eastern slopes of the Western Ghats and Odisha. Teak, sal, shisham, hurra, mahua, amla, semul, kusum, and sandalwood etc. are the main species of these forests. Dry deciduous forest covers vast areas of the country, where rainfall ranges between 70 -100

cm. On the wetter margins, it has a transition to the moist deciduous, while on the drier margins to thorn forests. These forests are found in rainier areas of the Peninsula and the plains of Uttar Pradesh and Bihar. In the higher rainfall regions of the Peninsular plateau and the northern Indian plain, these forests have a parkland landscape with open stretches in which teak and other trees interspersed with patches of grass are common. As the dry season begins, the trees shed their leaves completely and the forest appears like a vast grassland with naked trees all around. Tendu, palas, amaltas, bel, khair, axlewood, etc. are the common trees of these forests. In the western and southern part of Rajasthan, vegetation cover is very scanty due to low rainfall and overgrazing. Tropical Thorn Forests Tropical thorn forests occur in the areas which receive rainfall less than 50 cm. These consist of a variety of grasses and shrubs. It includes semi-arid areas of south west Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh. In these forests, plants remain leafless for most part of the year and give an expression of scrub vegetation. Important species found are babool, ber, and wild date palm, khair, neem, khejri, palas, etc. Tussocky grass grows upto a height of 2 m as the under growth. Montane Forests In mountainous areas, the decrease in temperature with increasing altitude leads to a corresponding change in natural vegetation. Mountain forests can be classified into two types, the northern mountain forests and the southern mountain forests. Figure 5.3 : Deciduous Forests Figure 5.4 : Tropical Thorn Forests Rationalised 2023-24 NATURAL VEGETATION 45 The Himalayan ranges show a succession of vegetation from the tropical to the tundra, which change in with the altitude. Deciduous forests are found in the foothills of the Himalayas. It is succeeded by the wet temperate type of forests between an altitude of 1,000-2,000 m. In the higher hill ranges of northeastern India, hilly areas of West Bengal and Uttaranchal, evergreen broad leaf trees such as oak and chestnut are predominant. Between 1,500-1,750 m, pine forests are also well-developed in this zone, with Chir Pine as a very useful commercial tree. Deodar, a highly valued endemic species grows mainly in the western part of the Himalayan range. Deodar is a durable wood mainly used in construction activity. Similarly, the chinar and the walnut, which sustain the famous Kashmir handicrafts, belong to this zone. Blue pine and spruce appear at altitudes of 2,225-3,048 m. At many places in this zone, temperate grasslands are also found. But in the higher reaches there is a transition to Alpine forests and pastures. Silver firs, junipers, pines, birch and rhododendrons, etc. occur between 3,000-4,000 m. However, these pastures are used extensively for transhumance by tribes like the Gujjars, the Bakarwals, the Bhotiyas and the Gaddis. The southern slopes of the Himalayas carry a thicker vegetation cover because of relatively higher precipitation than the drier north-facing slopes. At higher altitudes, mosses and lichens form part of the tundra vegetation. The southern mountain forests include the forests found in three distinct areas of Peninsular India viz; the Western Ghats, the Vindhyas and the Nilgiris. As they are closer to the tropics, and only 1,500 m above the sea level, vegetation is temperate in the higher regions, and subtropical on the lower regions of the Western Ghats, especially in Kerala, Tamil Nadu and Karnataka. The temperate forests are called Sholas in the Nilgiris, Anaimalai and Palani hills. Some of the other trees of this forest of economic significance include, magnolia, laurel, cinchona and wattle. Such forests are also found in the Satpura and the Maikal ranges. Littoral and Swamp Forests India has a rich variety of wetland habitats. About 70 per cent of this comprises areas under paddy cultivation. The total area of wet land is 3.9 million hectares. Two sites — Chilika Lake (Odisha) and Keoladeo National Park (Bharatpur) are protected as water-fowl habitats under the Convention of Wetlands of International Importance (Ramsar Convention). An international convention is an agreement among member states of the United Nations. The country's wetlands have been grouped into eight categories, viz. (i) the reservoirs of the Deccan Plateau in the south together with the lagoons and other wetlands of the southern west coast; (ii) the vast saline expanses of Rajasthan, Gujarat and the Gulf of Kachchh; (iii) freshwater lakes and reservoirs from Gujarat eastwards through Rajasthan (Keoladeo National Park) and Madhya Pradesh; (iv) the delta wetlands and lagoons of

India’s east coast (Chilika Lake); (v) the freshwater marshes of the Gangetic Plain; (vi) the floodplains of the Brahmaputra; the marshes and swamps in the hills of northeast India and the Himalayan foothills; (vii) the lakes and rivers of the montane region of Kashmir and Ladakh; and (viii) the mangrove forest and other wetlands of the island arcs of the Andaman and Nicobar Islands. Mangroves grow along the coasts in the salt Figure 5.5 : Montane Forests marshes, tidal creeks, mud flats and estuaries. Rationalised 2023-24 46 INDIA : PHYSICAL ENVIRONMENT They consist of a number of salt-tolerant species of plants. Crisscrossed by creeks of stagnant water and tidal flows, these forests give shelter to a wide variety of birds. In India, the mangrove forests spread over 6,740 sq. km which is 7 per cent of the world’s mangrove forests. They are highly developed in the Andaman and Nicobar Islands and the Sunderbans of West Bengal. Other areas of significance are the Mahanadi, the Godavari and the Krishna deltas. These forests too, are being encroached upon, and hence, need conservation. FOREST CONSERVATION Forests have an intricate interrelationship with life and environment. These provide numerous direct and indirect advantages to our economy and society. Hence, conservation of forest is of vital importance to the survival and prosperity of humankind. Accordingly, the Government of India proposed to have a nation-wide forest conservation policy, and adopted a forest policy in 1952, which was further modified in 1988. According to the new forest policy, the Government will emphasise sustainable forest management in order to conserve and expand forest reserve on the one hand, and to meet the needs of local people on the other. The forest policy aimed at : (i) bringing 33 per cent of the geographical areas under forest cover; (ii) maintaining environmental stability and to restore forests where ecological balance was disturbed; (iii) conserving the natural heritage of the country, its biological diversity and genetic pool; (iv) checks soil erosion, extension of the desert lands and reduction of floods and droughts; (v) increasing the forest cover through social forestry and afforestation on degraded land; (vi) increasing the productivity of forests to make timber, fuel, fodder and food available to rural population dependant on forests, and encourage the substitution of wood; (vii) creating of a massive peoples movement involving women to encourage planting of trees, stop felling of trees and thus, reduce pressure on the existing forest. Forests and Life To a vast number of tribal people, the forest is a home, a livelihood, their very existence. It provides them food, fruits of all kinds, edible leaves, honey, nourishing roots and wild game. It provides them with material to build their houses and items for practising their arts. The importance of forests in tribal economy is well-known as they are the source of sustenance and livelihood for tribal communities. It is commonly believed that the tribal communities live in harmony with nature and protect forests. Forest and tribals are very closely related. The age-old knowledge of tribals regarding forestry can be used in the development of forests. Rather than treating tribals as minor forest produce collectors they should be made growers of minor forest produce and encouraged to participate in conservation. Figure 5.6 : Mangrove Forests Based on the forest conservation policy the following steps were initiated: Social Forestry Social forestry means the management and protection of forests and afforestation on barren lands with the purpose of helping in the environmental, social and rural development. The National Commission on Agriculture (1976) has classified social forestry into three Rationalised 2023-24 NATURAL VEGETATION 47 categories. These are Urban forestry, Rural forestry and Farm forestry. Urban forestry pertains to the raising and management of trees on public and privately owned lands in and around urban centres such as green belts, parks, roadside avenues, industrial and commercial green belts, etc. Rural forestry lays emphasis on promotion of agro-forestry and community-forestry. Agro-forestry is the raising of trees and agriculture crops on the same land inclusive of the waste patches. It combines forestry with agriculture, thus, altering the simultaneous production of food, fodder, fuel, timber and fruit. Community forestry involves the raising of trees on public or community land such as the village pasture and temple land, roadside, canal bank, strips along railway lines, and schools etc. Community forestry programme aims at providing benefits to the community as a

whole. Community forestry provides a means under which the people of landless classes can associate themselves in treeraising and thus, get those benefits which otherwise are restricted for landowners. Farm Forestry Farm forestry is a term applied to the process under which farmers grow trees for commercial and non-commercial purposes on their farm lands. Forest departments of various states distribute seedlings of trees free of cost to small and medium farmers. Several lands such as the margins of agricultural fields, grasslands and pastures, land around homes and cow sheds may be used for raising trees under noncommercial farm forestry. WILDLIFE You would have visited a zoo and may have seen animals and birds in captivity. Wildlife of India is a great natural heritage. It is estimated that about 4-5 per cent of all known plant and animal species on the earth are found in India. The main reason for this remarkable diversity of life forms is the great diversity of the ecosystem which this country has preserved and supported through the ages. Over the years, their habitat has been disturbed by human activities and as a result, their numbers have dwindled significantly. There are certain species that are at the brink of extinction. Some of the important reasons of the declining of wildlife are as follows: (i) Industrial and technological advancement brought about a rapid increase in the exploitation of forest resources. (ii) More and more lands were cleared for agriculture, human settlement, roads, mining, reservoirs, etc. (iii) Pressure on forests mounted due to lopping for fodder and fuelwood and removal of small timber by the local people. (iv) Grazing by domestic cattle caused an adverse effect on wildlife and its habitat. (v) Hunting was taken up as a sport by the elite and hundreds of wild animals were killed in a single hunt. Now commercial poaching is rampant. (vi) Incidence of forest fire. It is being felt that conservation of wildlife is of great significance to the national as well as the world heritage along with the promotion of ecotourism. What steps have been initiated by the government in this direction? WILDLIFE CONSERVATION IN INDIA The protection of wildlife has a long tradition in India. Many stories of Panchtantra and Jungle Books, etc. have stood the test of time relating to the love for wildlife. These have a profound impact on young minds. In 1972, a comprehensive Wildlife Act was enacted, which provides the main legal framework for conservation and protection of wildlife in India. The two main objectives of the Act are; to provide protection to the endangered species listed in the schedule of the Act and to provide legal support to the conservation areas of the country classified as National parks, sanctuaries and closed areas. This Act has been Rationalised 2023-24 48 INDIA : PHYSICAL ENVIRONMENT comprehensively amended in 1991, making punishments more stringent and has also made provisions for the protection of specified plant species and conservation of endangered species of wild animals. There are 101 National parks and 553 wildlife sanctuaries in the country (Appendix V). Wildlife conservation has a very large ambit with unbounded potential for the wellbeing of humankind. However, this can be achieved only when every individual understands its significance and contributes his bit. For the purpose of effective conservation of flora and fauna, special steps have been initiated by the Government of India in collaboration with UNESCO's 'Man and Biosphere Programme'. Figure 5.7 : Elephants in their Natural Habitat Table 5.1 : List of Biosphere Reserves * Sites with bold letters have been included in the World Network of BRs of UNESCO. Source : Annual Report 2018-19, Ministry of Environment and Forests, Government of India. Sl. Name of the Biosphere Date of Location in the States/UT No. Reserve and Total Designation Geographical Area (km2 ) 1. Nilgiri (5520) 01.08.1986 Part of Wynad, Nagarhole, Bandipur and Madumalai, Nilambur, Silent Valley and Siruvani Hills (Tamil Nadu, Kerala and Karnataka). 2. Nanda Devi (5860.69) 18.01.1988 Part of Chamoli, Pithoragarh and Almora Districts in Uttarakhand. 3. Nokrek (820) 01.09.1988 Part of East, West and South Garo Hill Districts in Meghalaya. 4. Manas (2837) 14.03.1989 Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darang Districts in Assam 5. Sunderban (9630) 29.03.1989 Part of delta of Ganges and Brahamaputra river system in West Bengal. 6. Gulf of Mannar (10500) 18.02.1989 Indian part of Gulf of Mannar extending from Rameswaram island in the North to Kaniyakumari in the South of Tamil Nadu. 7. Great Nicobar (885)

06.01.1989 Southern most island of Andaman and Nicobar Islands. 8. Similipal (4374) 21.06.1994 Part of Mayurbhanj District in Odisha. 9. Dibru-Saikhowa (765) 28.07.1997 Part of Dibrugarh and Tinsukia Districts in Assam 10 Dehang Debang (5111.5) 02.09.1998 Part of Upper Siang, West Siang and Dibang Valley Districts in Arunachal Pradesh. 11. Pachmarhi (4981.72) 03.03.1999 Part of Betul, Hoshangabad and Chhindwara Districts in Madhya Pradesh. 12. Khangchendzonga (2619.92) 07.02.2000 Part of North and West Districts in Sikkim 13. Agasthyamalai (3500.36) 12.11.2001 Part of Thirunelveli and Kanyakumari Districts in Tamil Nadu and Thiruvananthapuram, Kollam and Pathanmthitta districts in Kerala. 14. Achanakmar-Amarkantak 30.03.2005 Part of Anuppur and Dindori Districts of Madhya Pradesh (3835.51) and Bilaspur district of Chhattisgarh 15. Kachchh (12,454) 29.01.2008 Part of Kachchh, Rajkot, Surendranagar and Patan Districts in Gujarat. 16. Cold Desert (7770) 28.08.2009 Pin Valley National Park and surroundings; Chandratal and Sarchu and Kibber Wildlife sanctuary in Himachal Pradesh. 17. Seshachalam (4755.997) 20.09.2010 Seshachalam hill ranges in Eastern Ghatsencompassing part of Chittoor and Kadapa Districts in Andhra Pradesh. 18. Panna (2998.98) 25.08.2011 Part of Pann and Chhattarpur Districts in Madhya Pradesh. Rationalised 2023-24 NATURAL VEGETATION 49 Figure 5.8 : India : Biosphere Reserves Rationalised 2023-24 50 INDIA : PHYSICAL ENVIRONMENT Figure 5.9 : Objectives of a Biosphere Reserve Special schemes like Project Tiger (1973) and Project Elephant (1992) have been launched to conserve these species and their habitat in a sustainable manner. Project Tiger has been implemented since 1973. The main objective of the scheme is to ensure maintenance of viable population of tigers in India for scientific, aesthetic, cultural and ecological values, and to preserve areas of biological importance as natural heritage for the benefit, education and enjoyment of the people. Initially, the Project Tiger was launched in nine tiger reserves, covering an area of 16,339 sq. km, which has now increased to 50 tiger reserves, encompassing 71,027.10 sq. km of core tiger habitats distributed in 18 states. The tiger population in the country has registered an increase from 1,411 in 2006 to 2,967 in 2020 which is 70 per cent of the global tiger population. Project Elephant was launched in 1992 to assist states having free ranging population of wild elephants. It was aimed at ensuring long-term survival of identified viable population of elephants in their natural habitat. The project is being implemented in 16 states. Apart from this, some other projects such as Crocodile Breeding Project, Project Hangul EXERCISES 1. Choose the right answer from the four alternatives given below. (i) Sandalwood is an example of: (a) Evergreen forest (c) Deltaic forest (b) Deciduous forest (d) Thorny forest (ii) Which one of the following was the purpose of Project Tiger? (a) to kill tigers (c) to protect tigers from illegal hunting (b) to put tigers in the Zoo (d) to make films on tigers (iii) In which one of the following states is the Nandadevi Biosphere reserve situated? (a) Bihar (c) Uttarakhand (b) Uttar Pradesh (d) Odisha and conservation of Himalayan Musk deer have also been launched by the Government of India. BIOSPHERE RESERVES A Biosphere Reserve is a unique and representative ecosystem of terrestrial and coastal areas which are internationally recognised within the framework of UNESCO's Man and Biosphere (MAB) Programme. The Biosphere Reserve aims at achieving the three objectives as depicted in Figure 5.9. There are 18 Biosphere Reserves in India (Table 5.1, Figure 5.8). Eleven Biosphere Reserves have been recognised by the UNESCO on World Network of Biosphere Reserves. Rationalised 2023-24 NATURAL VEGETATION 51 (iv) How many of the Biosphere reserves from India are recognised by the UNESCO? (a) One (c) Eleven (b) Two (d) Four (v) Which one of the following proportion of area of the country was targeted to be under forest in Forest Policy of India? (a) 3 3 (c) 5 5 (b) 4 4 (d) 2 2 2. Answer the following questions in about 30 words. (i) What is natural vegetation? Under what climatic conditions are tropical evergreen forests develop? (ii) What do you understand by social forestry? (iii) Define Biosphere reserves? (iv) What is the difference between forest area and forest cover? 3. Answer the following questions in not more than 150 words. (i) What steps have been taken up to conserve forests? (ii) How can people's participation be effective in conserving forests and wildlife? Project/Activity 1. On the outline map of India, mark and label the

following. (i) Areas having Mangrove forests. (ii) Biosphere reserves of Nanda Devi, Sunderbans, Gulf of Mannar and Nilgiri. (iii) Mark the location of Forest Survey of India Head Quarter. 2. List the trees, bush and shrub species found around your school. Write their local names and their uses. Rationalised 2023-24NATURAL HAZARDS AND DISASTERS: CAUSES, CONSEQUENCES AND MANAGEMENT This unit deals with • Floods and droughts • Earthquakes and tsunami • Cyclones • Landslides UNIT IV Rationalised 2023-24 Y ou might have read about tsunami or seen the images of horror on television set immediately after it happened. You may also be aware of the severe earthquake in Kashmir on both sides of the Line of Control (LOC). The damage caused to human life and properties during these episodes has moved us all. What are these as phenomena and how they are caused? How can we save ourselves? These are some questions which come to our minds. This chapter will attempt to analyse some of these questions. Change is the law of nature. It is a continuous process that goes on uninterruptedly involving phenomena, big and small, material and nonmaterial that make our physical and sociocultural environment. It is a process present everywhere with variations in terms of magnitude, intensity and scale. Change can be a gradual or slow process like the evolution of landforms and organisms and it can be as sudden and swift as volcanic eruptions, tsunamis, earthquakes and lightening, etc. Similarly, it may remain confined to a smaller area occurring within a few seconds like hailstorms, tornadoes and dust storms, and it can also have global dimensions such as global warming and depletion of the ozone layer. Besides these, changes have different meanings for different people. It depends upon the perspective one takes while trying to understand them. From the perspective of nature, changes are value-neutral (these are neither good nor bad). But from the human perspective, these are value-loaded. There are some changes that are desirable and good like the change of seasons, ripening of fruits, while there are others like earthquakes, floods and wars that are considered bad and undesirable. Observe the environment you live in and prepare a list of changes, which take place over a long period of time and those, which take place within a short period of time. Do you know why some changes are considered good and others bad? Prepare a list of changes, which you notice in your daily life and give reasons why some of these are considered good and others bad. In this chapter, we will read about some of these changes, which are considered bad and have haunted humankind for a long time. Disasters in general and natural disasters in particular, are some such changes that are always disliked and feared by humankind. What is a Disaster? “Disaster is an undesirable occurrence resulting from forces that are largely outside human control, strikes quickly with little or no warning, which causes or threatens serious disruption of life and property including death and injury to a large number of people, and requires therefore, mobilisation of efforts in excess of that which are normally provided by statutory emergency services”. For a long time, geographical literature viewed disasters as a consequence of natural forces; and human beings were treated as innocent and helpless victims in front of the mighty forces of nature. But natural forces are NATURAL HAZARDS AND DISASTERS CHAPTER Rationalised 2023-24 54 INDIA : PHYSICAL ENVIRONMENT not the only causes of disasters. Disasters are also caused by some human activities. There are some activities carried by human beings that are directly responsible for disasters. Bhopal Gas tragedy, Chernobyl nuclear disaster, wars, release of CFCs (Chlorofluorocarbons) and increase of green house gases, environmental pollutions like noise, air, water and soil are some of the disasters which are caused directly by human actions. There are some other activities of human beings that accelerate or intensify disasters indirectly. Landslides and floods due to deforestation, unscientific land use and construction activities in fragile areas are some of the disasters that are the results of indirect human actions. Can you identify some other human activities going on in and around your neighbourhood and schools that can lead to disasters in the near future? Can you suggest some measures to prevent it? It is a common experience that human-made disasters have increased both in their numbers and magnitudes over the years and concerted efforts are on at various levels to prevent and minimise

their occurrences. Though the success has been only nominal so far, it is possible to prevent some of these disasters created by human actions. As opposed to this, very little is possible to prevent natural disasters; therefore, the best way out is to emphasise on natural disaster mitigation and management. Establishment of National Institute of Disaster Management, India, Earth Summit at Rio de Janeiro, Brazil, 1993 and the World Conference on Disaster Management in May 1994 at Yokohama, Japan, etc. are some of the concrete steps towards this direction initiated at different levels. Most often it is observed that scholars use disasters and natural hazards as interchangeable. Both are related phenomena, yet quite distinct from each other. Hence, it is necessary to distinguish between the two. Natural Hazards are elements of circumstances in the Natural environment that have the potential to cause harm to people or property or both. These may be swift or permanent aspects of the respective environmental settings like currents in the oceans, steep slope and unstable structural features in the Himalayas or extreme climatic conditions in deserts or glaciated areas. As compared to natural hazards, natural disasters are relatively sudden and cause large scale, widespread death, loss of property and disturbance to social systems and life over which people have a little or no control. Thus, any event can be classed as disaster when the magnitude of destruction and damage caused by it is very high. Generally, disasters are generalised experiences of people the world over, and no two disasters are similar and comparable to each other. Every disaster is unique in terms of the local socio-environmental factors that control it, the social response it generates, and the way each social group negotiates with it. However, the opinion mentioned above is indicative of three important things. Firstly, the magnitude, intensity, frequency and damages caused by natural disasters have increased over the years. Secondly, there is a growing concern among people the world over to deal with the menace created by these so that the loss of human life and property can be minimised. And finally, significant changes have taken place in the pattern of natural disasters over the years. There has also been a change in the perception of natural disasters and hazards. Previously, hazards and disasters were seen as two closely associated and interrelated phenomena, i.e. areas prone to natural hazards, were more vulnerable to disasters. Hence, people avoided tampering with the delicate balance that existed in a given ecosystem. People avoided intensification of their activities in such areas and that is how disasters were less damaging. Technological power has given large capacity to human intervention in nature. Consequently, now, human beings tend to intensify their activities into disaster prone areas increasing their vulnerability to disasters. Colonisation of flood plains of most of the rivers and development of large cities and port-towns like – Mumbai and Chennai along the coast, and touching the shore due to high land values, make them vulnerable to the occurrence of cyclones, hurricanes and tsunamis. Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 55 These observations can also be corroborated by the data given in Table 7.1 showing the magnitude of deaths caused by twelve serious natural disasters in the past sixty years in different countries of the world. It is evident from the table that natural disasters have caused widespread loss of life and property. Concerted efforts are on at various levels to take appropriate measures to deal with the situation. It is also being felt that the damages caused by natural disasters have global repercussions that are beyond the means and capabilities of individual nation-states to cope up with. Hence, this issue was raised at the U.N. General Assembly in 1989 and it was finally formalised at the World Conference on Disaster Management in May 1994 at Yokohama, Japan. This was subsequently called the Yokohama Strategy and Plan of Action for a Safer World. CLASSIFICATION OF NATURAL DISASTERS Human beings the world over have experienced disasters and have faced and lived with them. Now people are becoming aware and various steps have been initiated at different levels for mitigating the effects of disasters. Identification and classification of disasters is being considered as an effective and scientific step to deal promptly and efficiently with the disasters. Broadly, natural disasters can be classified under four categories (See Table 6.2). India is one of those countries which has experienced most of the natural disasters

mentioned in Table 6.2. Every year it loses thousands of lives and property worth millions of rupees due to these natural calamities. In the following section, some of the highly devastating natural disasters have been discussed, particularly in the context of India. NATURAL DISASTERS AND HAZARDS IN INDIA It was discussed in one of the previous chapters that India is vast and diverse in terms of its physical and socio-cultural attributes. It is largely due to its vast geographical area, environmental diversities and cultural pluralities that scholars often described it using two meaningful adjectives like the 'Indian-subcontinent' and the 'land of unity in diversity'. Its vastness in terms of natural attributes combined with its prolonged colonial past, continuing various forms of social discriminations and also equally large population have enhanced its vulnerability to natural disasters. These observations can also be illustrated by focussing on some of the major natural disasters in India. Earthquakes Earthquakes are by far the most unpredictable and highly destructive of all the natural disasters. You have already learnt the causes of earthquakes in your book Fundamentals of Physical Geography (NCER T, 2006). Earthquakes that are of tectonic origin have proved to be the most devastating and their area of influence is also quite large. These earthquakes result from a series of earth movements brought about by a sudden release of energy during the tectonic activities in the earth's crust. As compared to these, the earthquakes associated with volcanic eruption, rock fall, landslides, subsidence, particularly in the mining areas, impounding of dams and reservoirs, etc. have limited area of influence and the scale of damage. It was mentioned in Chapter 2 of the book that the Indian plate is moving at a speed of one centimetre per year towards the north and northeastern direction and this movement of plates is being constantly obstructed by the Eurasian plate from the north. As a result of this, Figure 6.1 : A Damaged Building Due to an Earthquake Rationalised 2023-24 56 INDIA : PHYSICAL ENVIRONMENT Yokohama Strategy and International Decade for Natural Disaster Reduction (IDNDR) Yokohama Strategy and Plan of Action for a Safer World All the member states of the United Nations and other states met at the World Conference on Natural Disaster Reduction in the city of Yokohama from May 23rd-27th 1994. It acknowledged that the impact of natural disasters in terms of human and economic losses has risen in recent years, and society, in general, has become vulnerable to natural disasters. It also accepted that these disasters affected the poor and disadvantageous groups the worst, particularly in the developing countries, which are ill-equipped to cope with them. Hence, the conference adopted the Yokohama strategy as a guide to rest of the decade and beyond, to mitigate the losses due to these disasters. The resolution of the World Conference on Natural Disasters Reduction is as mentioned below: (i) It will note that each country has the sovereign responsibility to protect its citizens from natural disasters; (ii) It will give priority attention to the developing countries, particularly the least developed, land-locked countries and small-island developing states; (iii) It will develop and strengthen national capacities and capabilities and, where appropriate, national legislation for natural and other disaster prevention, mitigation and preparedness, including the mobilisation of non-governmental organisations and participation of local communities; (iv) It will promote and strengthen sub-regional, regional and international cooperation in activities to prevent, reduce and mitigate natural and other disasters, with particular emphasis on: (a) human and institutional capacity-building and strengthening; (b) technology sharing: the collection, the dissemination and utilisation of information; and (c) mobilisation of resources. It also declared the decade 1990-2000 as the International Decade for Natural Disaster Reduction (IDNDR). both the plates are said to be locked with each other resulting in accumulation of energy at different points of time. Excessive accumulation of energy results in building up of stress, which ultimately leads to the breaking up of the lock and the sudden release of energy causes earthquakes along the Himalayan arch. Some of the most vulnerable union territories/states are Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, and the Darjeeling subdivision of West Bengal, and all the seven states of the northeast. Apart from these regions, the central-western parts of India,

particularly Gujarat (in 1819, 1956 and 2001) and Maharashtra (in 1967 and 1993) have also experienced some severe earthquakes. Earth scientists have found it difficult to explain the occurrence of earthquakes in one of the oldest, most stable and mature landmass of Peninsular block for a long time. Recently, some earth scientists have come up with a theory of emergence of a fault line and energy build-up along the fault line represented by the river Bhima (Krishna) near Latur and Osmanabad (Maharashtra) and the possible breaking down of the Indian plate (Figure 6.2). National Geophysical Laboratory, Geological Survey of India, Department of Meteorology, Government of India, along with the recently formed National Institute of Disaster Management, have made an intensive analysis of more than 1,200 earthquakes that have occurred in India in different years in the past, and based on these, they divided India into the following five earthquake zones: (i) Very high damage risk zone (ii) High damage risk zone (iii) Moderate damage risk zone (iv) Low damage risk zone (v) Very low damage risk zone. Out of these, the first two zones had experienced some of the most devastating earthquakes in India. As shown in the Figure 6.2, areas vulnerable to these earthquakes are the North-east states, areas to the north of Darbhanga and Araria along the Indo-Nepal border in Bihar, Uttarakhand, Western Himachal Pradesh (around Dharamshala) and Kashmir Valley in the Himalayan region and the Kuchchh (Gujarat). These are included in the Very High Damage Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 57 Risk Zone. Similarly, the remaining parts of Jammu and Kashmir, Ladakh, Himachal Pradesh, Northern parts of Punjab, Eastern parts of Haryana, Delhi, Western Uttar Pradesh, and Northern Bihar fall under the High Damage Risk Zone. Remaining parts of the country fall under moderate to very Low Damage Risk Zone. Most of the areas that can be considered safe are from the stable landmass covered under the Deccan plateau. Socio-Environmental Consequences of Earthquakes The idea of an earthquake is often associated with fear and horror due to the scale, magnitude and suddenness at which it spreads disasters on the surface of the earth without discrimination. It becomes a calamity when it strikes the areas of high density of population. It not only damages and destroys the settlements, infrastructure, transport and communication network, industries and other developmental activities but also robs the population of their material and socio-cultural gains that they have preserved over generations. It renders them homeless, which puts an extra-pressure and stress, particularly on the weak economy of the developing countries. Effects of Earthquakes Earthquakes have all encompassing disastrous effects on the area of their occurrence. Some of the important ones are listed in Table 6.1. fissures on the upper layers of the earth’s crust through which water and other volatile materials gush out, inundating the neighbouring areas. Earthquakes are also responsible for landslides and often these cause obstructions in the flow of rivers and channels resulting in the formation of reservoirs. Sometimes, rivers also change their course causing floods and other calamities in the affected areas. Earthquake Hazard Mitigation Unlike other disasters, the damages caused by earthquakes are more devastating. Since it also destroys most of the transport and communication links, providing timely relief to the victims becomes difficult. It is not possible to prevent the occurrence of an earthquake; hence, the next best option is to emphasis on disaster preparedness and mitigation rather than curative measures such as: (i) Establishing earthquake monitoring centres (seismological centres) for regular monitoring and fast dissemination of information among the people in the vulnerable areas. Use of Geographical Positioning System (GPS) can be of great help in monitoring the movement of tectonic plates. (ii) Preparing a vulnerability map of the country and dissemination of vulnerability risk information among the people and educating them about the ways and means minimising the adverse impacts of disasters. (iii) Modifying the house types and building-designs in the vulnerable areas and discouraging construction of highrise buildings, large industrial establishments and big urban centres in such areas. (iv) Finally, making it mandatory to adopt earthquake-resistant designs and use light materials in major construction activities in the vulnerable areas. Apart from these, earthquakes also have some serious and far-

reaching environmental consequences. Surface seismic waves produce Table 6.1 : Effects of Earthquakes On Ground On Manmade On Water Structures Fissures Cracking Waves Settlements Slidings Hydro-Dynamic Pressure Landslides Overturning Tsunami Liquefaction Buckling Earth Pressure Collapse Possible Chain-effects Possible Possible Chain-effects Chain-effects Rationalised 2023-24 58 INDIA : PHYSICAL ENVIRONMENT Figure 6.2 : India: Earthquake Hazard Zones Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 59 Tsunami Earthquakes and volcanic eruptions that cause the sea-floor to move abruptly resulting in sudden displacement of ocean water in the form of high vertical waves are called tsunamis (harbour waves) or seismic sea waves. Normally, the seismic waves cause only one instantaneous vertical wave; but, after the initial disturbance, a series of afterwaves are created in the water that oscillate between high crest and low trough in order to restore the water level. The speed of wave in the ocean depends upon the depth of water. It is more in the shallow water than in the ocean deep. As a result of this, the impact of tsunami is less over the ocean and more near the coast where they cause large-scale devastations. Therefore, a ship at sea is not much affected by tsunami and it is difficult to detect a tsunami in the deeper parts of sea. It is so because over deep water the tsunami has very long wave-length and limited wave-height. Thus, a tsunami wave raises the ship only a metre or two and each rise and fall takes several minutes. As opposed to this, when a tsunami enters shallow water, its wave-length gets reduced and the period remains unchanged, which increases the waveheight. Sometimes, this height can be up to 15m or more, which causes large-scale destructions along the shores. Thus, these are also called Shallow Water Waves. Tsunamis are frequently observed along the Pacific ring of fire, particularly along the coast of Alaska, Japan, Philippines, and other islands of Southeast Asia, Indonesia, Malaysia, Myanmar, Sri Lanka, and India etc. After reaching the coast, the tsunami waves release enormous energy stored in them and water flows turbulently onto the land destroying port-cities and towns, structures, buildings and other settlements. Since the coastal areas are densely populated the world over, and these are also centres of intense human activity, the loss of life and property is likely to be much higher by a tsunami as compared to other natural hazards in the coastal areas. The extent of devastation caused by tsunami can be assessed through the visuals on Banda Ache (Indonesia) presented in the book Practical Work in Geography - Part I (NCERT, 2006). Unlike other natural hazards, the mitigation of hazards created by tsunami is difficult, mainly because of the fact that losses are on a much larger scale. It is beyond the capacity of individual state or government to mitigate the damage. Hence, combined efforts at the international levels are the possible ways of dealing with these disasters as has been in the case of the tsunami that occurred on 26th December 2004 in which more than 300,000 people lost their lives. India has volunteered to join the International Tsunami Warning System after the December 2004 tsunami disaster. Tropical Cyclone Tropical cyclones are intense low-pressure areas confined to the area lying between 30° N and 30°° S latitudes, in the atmosphere around which high velocity winds blow. Horizontally, it extends up to 500-1,000 km and vertically from surface to 12-14 km. A tropical cyclone or hurricane is like a heat engine that is energised by the release of latent heat on account of the condensation of moisture that the wind gathers after moving over the oceans and seas. There are differences of opinion among scientists about the exact mechanism of a tropical cyclone. However, some initial conditions for the emergence of a tropical cyclone are: Figure 6.3 : Tsunami Affected Area Rationalised 2023-24 60 INDIA : PHYSICAL ENVIRONMENT A surge is generated due to interaction of air, sea and land. The cyclone provides the driving force in the form of very high horizontal pressure-gradient and very strong surface winds. The sea water flows across the coast along with strong winds and heavy downpour. This results in inundation of human settlements, agricultural fields, damaging crops and destruction of structures created by human beings. Floods You read in newspapers and watch images of floods on televisions occurring in some regions during rainy seasons. Inundation of land and human settlements by the rise of water in the channels and its spill-over presents the condition of

flooding. Unlike other natural disasters, the causes of floods are wellestablished. Floods are relatively slow in occurrences and often, occur in well-identified regions and within expected time in a year. Floods occur commonly when water in the form of surface run-off exceeds the carrying capacity of the river channels and streams and flows into the neighbouring low-lying flood plains. At times, this even goes beyond the capacity of lakes and other inland water bodies in which they flow. Floods can also be caused due to a storm surge (in the coastal areas), high intensity rainfall for a considerably longer time period, melting of ice and snow, reduction in the infiltration rate and presence of eroded material in the water due to higher rate of soil erosion. Though floods occur frequently over wide geographical area having disasterous ramifications in many parts of the world, floods in the South, Southeast and East Asian countries, particularly in China, India and Bangladesh, are frequent and equally disastrous. Once again, unlike other natural disasters, human beings play an important role in the genesis as well as spread of floods. Indiscriminate deforestation, unscientific agricultural practices, disturbances along the natural drainage channels and colonisation of flood-plains and river-beds are some of the human activities that play an important role (i) Large and continuous supply of warm and moist air that can release enormous latent heat. (ii) Strong Coriolis force that can prevent filling of low pressure at the centre (absence of Coriolis force near the equator prohibits the formation of tropical cyclone between 0°-5° latitude). (iii) Unstable condition through the troposphere that creates local disturbances around which a cyclone develops. (iv) Finally, absence of strong vertical wind wedge, which disturbs the vertical transport of latent heat. Spatio-temporal Distribution of Tropical Cyclone in India Owing to its Peninsular shape surrounded by the Bay of Bengal in the east and the Arabian Sea in the west, the tropical cyclones in India also originate in these two important locations. Though most of the cyclones originate between 10°-15° north latitudes during the monsoon season, yet in case of the Bay of Bengal, cyclones mostly develop during the months of October and November. Here, they originate between 16°-2°° N latitudes and to the west of 92° E. By July the place of origin of these storms shifts to around 18° N latitude and west of 90°E near the Sunderban Delta. Consequences of Tropical Cyclones It was mentioned that the energy to the tropical cyclone comes from the latent heat released by the warm moist air. Hence, with the increase in distance from the sea, the force of the cyclone decreases. In India, the force of the cyclone decreases with increase in distance from the Bay of Bengal and the Arabian Sea. So, the coastal areas are often struck by severe cyclonic storms with an average velocity of 180 km/h. Often, this results in abnormal rise in the sea level known as Storm Surge. Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 61 Figure 6.4 : Wind and Cyclone Hazard Zones Rationalised 2023-24 62 INDIA : PHYSICAL ENVIRONMENT in increasing the intensity, magnitude and gravity of floods. Various states of India face heavy loss of lives and property due to recurrent floods. Rashtriya Barh Ayog (National Flood Commission) identified 40 million hectares of land as floodprone in India. The Figure 6.6 shows the floodaffected areas in India. Assam, West Bengal and Bihar are among the high flood-prone states of India. Apart from these, most of the rivers in the northern states like Punjab and Uttar Pradesh, are also vulnerable to occasional floods. It has been noticed that states like Rajasthan, Gujarat, Haryana and Punjab are also getting inundated in recent decades due to flash floods. This is partly because of the pattern of the monsoon and partly because of blocking of most of the streams and river channels by human activities. Sometimes, Tamil Nadu experiences flooding during November-January due to the retreating monsoon. Consequence and Control of Floods Frequent inundation of agricultural land and human settlement, particularly in Assam, West Bengal, Bihar and Eastern Uttar Pradesh (flooding rivers), coastal areas of Odisha, Andhra Pradesh, Tamil Nadu and Gujarat (cyclone) and Punjab, Rajasthan, Northern Gujarat and Haryana (flash floods) have serious consequences on the national economy and society. Floods do not only destroy valuable crops every year but these also damage physical infrastructure such as roads, rails, bridges and human settlements. Millions of people are rendered homeless and are also washed down along with their

cattle in the floods. Spread of diseases like cholera, gastro-enteritis, hepatitis and other waterborne diseases spread in the flood-affected areas. However, floods also make a few positive contributions. Every year, floods deposit fertile silt over agricultural fields which is good for the crops. Majuli (Assam), the largest riverine island in the world, is the best example of good paddy crops after the annual floods in Brahmaputra. But these are insignificant benefits in comparison to the grave losses. The Government of India as well as the state governments are well aware of the menace created by floods every year. How do these governments generally respond to the floods? Construction of flood protection embankments in the flood-prone areas, construction of dams, afforestation and discouraging major construction activities in the upper reaches of most of the flood-creating rivers, etc. are some steps that need to be taken up on urgent basis. Removal of human encroachment from the river channels and depopulating the flood plains can be the other steps. This is particularly true in western and northern parts of the country which experience flash-floods. Cyclone centres may provide relief in coastal areas which are hit by a storm surge. Figure 6.5 : Brahmaputra During Flood Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 63 Figure 6.6 : Flood Hazard Zones Dibang R. Lohit R. Rationalised 2023-24 64 INDIA : PHYSICAL ENVIRONMENT Droughts The term 'drought' is applied to an extended period when there is a shortage of water availability due to inadequate precipitation, excessive rate of evaporation and over-utilisation of water from the reservoirs and other storages, including the ground water. Drought is a complex phenomenon as it involves elements of meteorology like precipitation, evaporation, evapotranspiration, ground water, soil moisture, storage and surface run-off, agricultural practices, particularly the types of crops grown, socio-economic practices and ecological conditions. Types of Droughts Meteorological Drought : It is a situation when there is a prolonged period of inadequate rainfall marked with mal-distribution of the same over time and space. Agricultural Drought : It is also known as soil moisture drought, characterised by low soil moisture that is necessary to support the crops, thereby resulting in crop failures. Moreover, if an area has more than 30 per cent of its gross cropped area under irrigation, the area is excluded from the drought-prone category. Hydrological Drought : It results when the availability of water in different storages and reservoirs like aquifers, lakes, reservoirs, etc. falls below what the precipitation can replenish. Ecological Drought : When the productivity of a natural ecosystem fails due to shortage of water and as a consequence of ecological distress, damages are induced in the ecosystem. Various parts of India experience these droughts recurrently which result in some serious socio-economic and ecological problems. Drought Prone Areas in India Indian agriculture has been heavily dependent on the monsoon rainfall. Droughts and floods are the two accompanying features of Indian climate. According to some estimates, nearly 19 per cent of the total geographical area of the country and 12 per cent of its total population suffer due to drought every year. About 30 per cent of the country's total area is identified as drought prone affecting around 50 million people. It is a common experience that while some parts of the country reel under floods, there are regions that face severe drought during the same period. Moreover, it is also a common sight to witness that one region suffers due to floods in one season and experiences drought in the other. This is mainly because of the large-scale variations and unpredictability in the behaviour of the monsoon in India. Thus, droughts are widespread and common phenomena in most parts of the country, but these are most recurrent and severe in some and not so in others. On the basis of severity of droughts, India can be divided into the following regions: Extreme Drought Affected Areas : It is evident from the Figure 6.7 that most parts of Rajasthan, particularly areas to the west of the Aravali hills, i.e. Marusthali and Kachchh regions of Gujarat fall in this category. Included here are also the districts like Jaisalmer and Barmer from the Indian desert that receive less that 90 mm average annual rainfall. Severe Drought Prone Area : Parts of eastern Rajasthan, most parts of Madhya Pradesh, eastern parts of Maharashtra, interior parts of Andhra Pradesh and Karnataka Plateau, northern parts of interior Tamil Nadu and southern parts of Jharkhand and

interior Odisha are included in this category. Moderate Drought Affected Area : Northern parts of Rajasthan, Haryana, southern districts of Uttar Pradesh, the remaining parts of Gujarat, Maharashtra except Konkan, Jharkhand and Coimbatore plateau of Tamil Nadu and interior Karnataka are included in this category. The remaining parts of India can be considered either free or less prone to the drought. Consequences of Drought Droughts have cascading effects on various other aspects of environment and society. Crop failure leading to scarcity of food grains (akal), Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 65 Figure 6.7 : Drought Prone Areas Rationalised 2023-24 66 INDIA : PHYSICAL ENVIRONMENT fodder (trinkal), inadequate rainfall, resulting in shortage of water (jalkal), and often shortage in all the three (trikal) is most devastating. Large-scale death of cattle and other animals, migration of humans and livestock are the most common sight to be seen in the droughtaffected areas. Scarcity of water compels people to consume contaminated water resulting in spread of many waterborne diseases like gastro-enteritis, cholera, hepatitis, etc. Droughts have both immediate as well as long-term disastrous consequences on the social and physical environments. Consequently, planning for drought has to take both aspects into consideration. Provision for the distribution of safe drinking water, medicines for the victims and availability of fodder and water for the cattle and shifting of the people and their livestock to safer places, etc. are some steps that need to be taken immediately. Identification of ground water potential in the form of aquifers, transfer of river water from the surplus to the deficit areas, and particularly planning for inter-linking of rivers and construction of reservoirs and dams, etc. should be given a serious thought. Remote sensing and satellite imageries can be useful in identifying the possible river-basins that can be inter-linked and in identifying the ground water potential. Dissemination of knowledge about drought-resistant crops and proper training to practise the same can be some of the long-term measures that will be helpful in drought-mitigation. Rainwater harvesting can also be an effective method in minimising the effects of drought. Observe the methods adopted for rooftop rainwater harvesting in your locality and suggest measures to make it more effective. Landslides Have you ever read about the blocking of roads to Srinagar or disruption of rail services by stones falling on the Konkan Railway track? It happens due to landslide, which is the rapid sliding of large mass of bedrocks. Disasters due to landslides, are in general, far less dramatic than due to earthquakes, volcanic eruptions, tsunamis and cyclones but their impact on the natural environment and national economy is in no way less severe. Unlike other disasters that are sudden, unpredictable and are largely controlled by macro or regional factors, landslides are largely controlled by highly localised factors. Hence, gathering information and monitoring the possibilities of landslide is not only difficult but also immensely costintensive. It is always difficult to define in a precise statement and generalise the occurrence and behaviour of a landslide. However, on the basis of past experiences, frequency and certain causal relationships with the controlling factors like geology, geomorphic agents, slope, land-use, vegetation cover and human activities, India has been divided into a number of zones. Landslide Vulnerability Zones Very High Vulnerability Zone : Highly unstable, relatively young mountainous areas in the Himalayas and Andaman and Nicobar, high rainfall regions with steep slopes in the Western Ghats and Nilgiris, the north-eastern regions, along with areas that experience frequent ground-shaking due to earthquakes, etc. and areas of intense human activities, particularly those related to construction of roads, dams, etc. are included in this zone. Figure 6.8 : Drought Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 67 High Vulnerability Zone : Areas that have almost similar conditions to those included in the very high vulnerability zone are also included in this category. The only difference between these two is the combination, intensity and frequency of the controlling factors. All the Himalayan states and the states from the north-eastern regions except the plains of Assam are included in the high vulnerability zones. Moderate to Low Vulnerability Zone : Areas that receive less precipitation such as TransHimalayan areas of Ladakh and Spiti (Himachal Pradesh), undulated yet stable relief and low precipitation areas in the Aravali, rain shadow areas in the

Western and Eastern Ghats and Deccan plateau also experience occasional landslides. Landslides due to mining and subsidence are most common in states like Jharkhand, Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Goa and Kerala. Other Areas : The remaining parts of India, particularly states like Rajasthan, Haryana, Uttar Pradesh, Bihar, West Bengal (except district Darjiling), Assam (except district Karbi Anglong) and Coastal regions of the southern States are safe as far as landslides are concerned. Consequences of Landslides Landslides have relatively small and localised area of direct influence, but roadblock, destruction of railway lines and channel-blocking due to rock-falls have farreaching consequences. Diversion of river courses due to landslides can also lead to flood and loss of life and property. It also makes spatial interaction difficult, risky as well as a costly affair, which, in turn, adversely affects the developmental activities in these areas. Mitigation It is always advisable to adopt area-specific measures to deal with landslides. Restriction on the construction and other developmental activities such as roads and dams, limiting agriculture to valleys and areas with moderate slopes, and control on the development of large settlements in the high vulnerability zones, should be enforced. This should be supplemented by some positive actions like promoting large-scale afforestation programmes and construction of bunds to reduce the flow of water. Terrace farming should be encouraged in the northeastern hill states where Jhumming (Slash and Burn/Shifting Cultivation) is still prevalent. DISASTER MANAGEMENT Disasters due to cyclones, unlike the ones caused by earthquakes, tsunamis and volcanic eruptions are more predictable in terms of the time and place of their occurrences. Moreover, with the help of development of techniques to monitor the behaviour of cyclones, their intensity, direction and magnitude, it has become possible to manage the cyclonic hazard to some extent. Construction of cyclone-shelters, embankments, dykes, reservoirs and afforestation to reduce the speed of the winds are some of the steps that can help in minimising the damages. However, increase in the loss of life and property in countries like India, Bangladesh, Myanmar, etc. in successive storms is largely due to high vulnerability of their population residing in the coastal areas. Figure 6.9 : Landslide Rationalised 2023-24 68 INDIA : PHYSICAL ENVIRONMENT Disaster Management Bill, 2005 The Disaster Management Bill, 2005, defines disaster as a catastrophe, mishap, calamity or grave occurrence affecting any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, environment, and is of such nature or magnitude as to be beyond the coping capacity of the community of the affected area. (i) Pre-disaster management involves generating data and information about the disasters, preparing vulnerability zoning maps and spreading awareness among the people about these. Apart from these, disaster planning, preparedness and preventive measures are other steps that need to be taken in the vulnerable areas. (ii) During disasters, rescue and relief operations such as evacuation, construction of shelters and relief camps, supplying of water, food, clothing and medical aids etc. should be done on an emergency basis. (iii) Post-disaster operations should involve rehabilitation and recovery of victims. It should also concentrate on capacitybuilding in order to cope up with future disasters, if any. These measures have special significance to a country like India, which has about twothird of its geographical area and equal proportion of its population, vulnerable to disasters. Introduction of the Disaster Management Bill, 2005 and establishment of National Institute of Disaster Management are some examples of the positive steps taken by the Government of India. CONCLUSION On the basis of the above discussion, it can be concluded that disasters can be natural or the results of human activities, and all hazards need not turn into disasters since it is difficult to eliminate disasters, particularly natural disasters. Then the next best option is mitigation and preparedness. There are three stages involved in disaster mitigation and management: Rationalised 2023-24 NATURAL HAZARDS AND DISASTERS 69 1. Choose the right answer from the four alternatives given below. (i) Which one of the following states of India experiences floods frequently? (a) Bihar (c) Assam (b) West Bengal (d) Uttar Pradesh (ii) In which one of the following

districts of Uttaranchal did Malpa Landslide disaster take place? (a) Bageshwar (c) Almora (b) Champawat (d) Pithoragarh (iii) Which one of the following states receives floods in the winter months? (a) Assam (c) Kerala (b) West Bengal (d) Tamil Nadu (iv) In which of the following rivers is the Majuli River Island situated? (a) Ganga (c) Godavari (b) Brahmaputra (d) Indus (v) Under which type of natural hazards do blizzards come? (a) Atmospheric (c) Terrestrial (b) Aquatic (d) Biological 2. Answer the following questions in less than 30 words. (i) When can a hazard become a disaster? (ii) Why are there more earthquakes in the Himalayas and in the north-eastern region of India? (iii) What are the basic requirements for the formation of a cyclone? (vi) How are the floods in Eastern India different from the ones in Western India? (v) Why are there more droughts in Central and Western India? 3. Answer the following questions in not more than 125 words. (i) Identify the Landslide-prone regions of India and suggest some measures to mitigate the disasters caused by these. (ii) What is vulnerability? Divide India into natural disaster vulnerability zones based on droughts and suggest some mitigation measures. (iii) When can developmental activities become the cause of disasters? Project/Activity Prepare a project report on any one of the topics given below. (i) Malpa Landslide (v) Tehri Dam/Sardar Sarovar (ii) Tsunami (vi) Bhuj/Latur Earthquakes (iii) Odisha and Gujarat Cyclones (vii) Life in a delta/riverine island (iv) Inter-linking of rivers (viii) Prepare a model of rooftop rainwater harvesting EXERCISES Rationalised 2023-24 70 INDIA : PHYSICAL ENVIRONMENT GLOSSARY Alluvial Plain : A level tract of land made up of alluvium or fine rock material brought down by a river. Archipelago : A group of islands that lie in fairly close proximity. Arid : Denoting any climate or region in which the rainfall is insufficient or barely sufficient to support vegetation. Backwater : A stretch of water that has become bypassed by the main flow of a stream, although still joined to it. It has a very low rate of flow. Bedrock : The solid rock lying beneath soil and weathered material. Biosphere Reserve : These are multi-purpose protected areas, where every plant and animal size is to be protected in its natural habitat. Its major objectives are : (i) to conserve and maintain diversity and integrity of the natural heritage in its full form, i.e. physical environment, the flora and the fauna; (ii) to promote research on ecological conservation and other aspects of environment at preservation; (iii) to provide facilities for education, awareness and explaining. Bunding : The practice of constructing embankments of earth or stone for conserving water and soil to increase crop production. Calcareous : Composed of or containing a high proportion of calcium carbonate. Catchment Area : The area drained by a major river and its tributaries. Climate : The average weather conditions of a sizeable area of the earth’s surface over a period of time (usually spread over a span of at least 30 years). Coast : The boundary between land and sea. It includes the strip of land that borders the sea shore. Coastal Plain : It is a flat low lying land between the coast and higher ground inland. Conservation : The protection of natural environment and natural resources for the future. It includes the management of minerals, landscape, soil and forests to prevent their destruction and over exploitation. Coral : It is a small calcium secreting marine polyp that occurs in colonies, mainly in warm shallow sea water. It forms the coral reefs. Depression : In meteorology; it denotes an area of relatively low atmospheric pressure, which is found mainly in temperate regions. It is also used as synonym for temperate cyclones. Estuary : The tidal mouth of a river where fresh and saline water get mixed. Fauna : The animal life of a given area or time. Fold : A bend in rock strata resulting from compression of an area of the earth’s crust. Glacier : A mass of snow and ice that moves slowly away from its place of accumulation carving gradually a broad and steepsided valley on its way. Gneiss : A coarse grained metamorphic rock with a banded structure. It is formed by the large scale application of heat and pressure associated with mountain building and volcanic activity. Gorge : A deep valley with steep and rocky side walls. Rationalised 2023-24 Gully Erosion : It is the erosion of the soil and rock by the concentration of runoff into gullies. Humus : The dead organic content of the soil. Island : A mass of land that is surrounded by water and is smaller than a continent. Jet Stream : A very strong and steady westerly wind blowing just below the

tropopause. Lake : A body of water that lives in a hollow in the earth's surface and is entirely surrounded by land. Landslide : A form of mass movement in which rock and debris moves rapidly downslope under the influence of gravity as a result of failure along a shear plane. Meander : A pronounced curve or loop in the course of a river channel. Monsoon : A complete reversal of winds over a large area leading to a change of seasons. National Park : A National park is an area which is strictly reserved for the protection of the wildlife and where activities such as forestry, grazing or cultivation are not allowed. Pass : A route through a mountain range which follows the line of a col or a gap. Peninsula : A piece of land jutting out into the sea. Plain : An extensive area of flat or gently undulating land. Plateau : An extensive elevated area of relatively flat land. Playa : The low flat central area of a basin of inland drainage. Playas occur in areas of low rainfall. Protected Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having limited degree of protection. In Protected Forests, all activities are permitted unless prohibited. Rapids : A stretch of swift flowing water where a river bed suddenly becomes steeper due to the presence of hard rocks. Reserved Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having full degree of protection. In Reserved Forests, all activities are prohibited unless permitted. Sanctuary : A sanctuary is an area, which is reserved for the conservation of animals only and operations such as harvesting of timber, collection of minor forest products are allowed so long as they do not affect the animals adversely. Soil Profile : It is the vertical section of soil from the ground surface to the parent rock. Subcontinent : A big geographical unit which stands out distinctly from the rest of the continent. Terai : A belt of marshy ground and vegetation on the lower parts of the alluvial fans. Tectonic : Forces originating within the earth and responsible for bringing widespread changes in the landform features. Unclassed Forest : An area recorded as forest but not included in reserved or protected forest category. Ownership status of such forests varies from state to state. Rationalised 2023-24 NOTES Rationalised 2023-24Abiotic : Non-living thing. Usually refers to the physical and chemical components of an organism's environment. Adiabatic Lapse Rate : The rate of change of temperature by an ascending or descending airmass. If no other non-adiabatic processes (i.e. no heat enters or leaves the system) occur (like condensation, evaporation and radiation), expansion causes the parcel of air to cool at a set rate of 0.98° per 100 m. The opposite occurs when a parcel of air descends in the atmosphere. The air in a descending parcel becomes compressed. Compression causes the temperature within the parcel to increase at a rate of 0.98° per 100 m. Air Mass : A body of air whose temperature and humidity characteristics, acquired in source region, remain relatively constant over a horizontal distance of hundreds to thousands of km. Air masses develop their climatic characteristics by remaining stationary over a source region for a number of days. Air masses are classified according to their temperature and humidity characteristics. Aphelion : It is the point in the Earth's orbit when it is farthest from the sun (152.5 million km). Aphelion occurs on the 3rd or 4th of July. Asthenosphere : Zone in the Earth's mantle that exhibits plastic properties. Located below the lithosphere at between 100 and 200 km. Atmospheric Pressure : Weight of the atmosphere on a surface. At sea-level, the average atmospheric pressure is 1013.25 mb. Pressure is measured by a device called a barometer. Aurora : Multicoloured lights that appear in the upper atmosphere (ionosphere) over the polar regions and visible from locations in the middle and high latitudes. Caused by the interaction of solar wind with oxygen and nitrogen gas in the atmosphere. Aurora in the Northern Hemisphere are called aurora borealis and aurora australis in the Southern Hemisphere. Batholith : A large mass of subsurface intrusive igneous rock that has its origins from mantle magma. Big Bang : Theory about the origin of universe. It suggests that about 15 billion years ago all of the matter and energy in the Universe was concentrated into an area smaller than an atom. At this instant, matter, energy, space and time were not existant. Then suddenly with a bang, the Universe began to expand at an incredible rate and matter, energy, space and time came into being. As the Universe expanded, matter began to coalesce into gas clouds, and then stars and

planets. Some scientists believe that this expansion is finite and will one day cease. After this point in time, the Universe will begin to collapse until a Big Crunch occurs. Biodiversity : The diversity of different species (species diversity), genetic variability among individuals within each species (genetic diversity), and variety of ecosystems (ecosystem diversity). Biomass : The weight of living tissues usually measured per unit area over a GLOSSARY Rationalised-2023-24 122 FUNDAMENTALS OF PHYSICAL GEOGRAPHY particular time interval. Can include the dead parts of organisms like bark, hair, and nails. Biome : Largest recognisable assemblage of animals and plants on the Earth. The distribution of the biomes is controlled mainly by climate. Calcification : A dry environment soil-forming process that results in the accumulation of calcium carbonate in surface soil layers. Caldera Volcano : Explosive type of volcano that leaves a large circular depression. Some of these depressions can be as large as 40 km in diameter. These volcanoes form when wet granitic magma quickly rises to the surface of the Earth. Chlorofluorocarbons (CFCs) : Is an artificially created gas that has become concentrated in the Earth's atmosphere. This very strong greenhouse gas is released from aerosol sprays, refrigerants, and the production of fumes. Cirrocumulus Clouds : Patchy white high altitude cloud composed of ice crystals. Found in an altitude range from 5,000 - 18,000 m. Cirrostratus Clouds : High altitude sheet like clouds composed of ice crystals. These thin clouds often cover the entire sky. Found in an altitude range from 5,000 - 18,000 m. Cold Front : A transition zone in the atmosphere where an advancing cold air mass displaces a warm air mass. Continental Crust : Granitic portion of the Earth's crust that makes up the continents. Thickness of the continental crust varies between 20 - 75 km. See sial layer. Coriolis Force : An apparent force due to the Earth's rotation. Causes moving objects to be deflected to the right in the Northern Hemisphere and to the left in the Southern hemisphere. Coriolis force does not exist on the equator. This force is responsible for the direction of flow in meteorological phenomena like mid-latitude cyclones, hurricanes, and anticyclones. Cumulus Cloud : Large clouds with relatively flat bases. These are found in an altitude range from 300 - 2,000 m. Cumulonimbus Cloud : A well developed vertical cloud that often has top shaped like an anvil. These clouds can extend in altitude from a few hundred m above the surface to more than 12,000 m. Desert Pavement : A veneer of coarse particles left on the ground after the erosion of finer particles by wind. Earthquake : A sudden motion or shaking in the Earth. The motion is caused by the quick release of slowly accumulated energy in the form of seismic waves. Earthquake Focus : Point of stress release in an earthquake (also known as hypocentre). Ebb Tide : Time during the tidal period when the water level in the sea is falling. Ecosystem : A system consisting of biotic and abiotic components. Both these groups are interrelated and interacting. El Nino : The name given to the occasional development of warm ocean surface waters along the coast of Ecuador and Peru. Recently this phenomenon has been used for forecasting of climatic conditions in different parts of the world. The El Nino normally occurs around Christmas and lasts usually for a few weeks to a few months. Rationalised-2023-24 GLOSSARY 123 Epicentre : A place on the surface of the earth located at the shortest distance from the focus of the earthquake, the point at which the seismic energy gets released. Global Warming : Warming of the Earth's average global temperature because of an increase in the concentration of greenhouse gases. Geomagnetism : A property of magnetically susceptible minerals to get aligned to the earth's magnetic field during the period of rock formation. Geostrophic Wind : Horizontal wind in the upper atmosphere that moves parallel to isobars. Results from a balance between pressure gradient force and Coriolis force. Greenhouse Effect : The greenhouse effect causes the atmosphere to trap more heat energy at the Earth's surface and within the atmosphere by absorbing and re-emitting longwave energy. Greenhouse Gases : Gases responsible for the greenhouse effect. These gases include: carbon dioxide ($CO_2$ ); methane ($CH_4$ ); nitrous oxide ($N_2O$); chlorofluorocarbons (CFC); and tropospheric ozone ($O_3$ ). Habitat : Location where a plant or animal lives. Hail : It is a type of precipitation received in the form of ice pellets or hail stones. The size of hailstones can be between 5 and 190 mm in diameter. Halocline :

The dinstinct zone in the ocean below which the salinity increases sharply. Hydration : A form of chemical weathering that involves the rigid attachment of H+ and OH- ions to the atoms and molecules of a mineral. Hydrolysis : Chemical weathering process that involves the reaction between mineral ions and the ions of water (OH- and H+), and results in the decomposition of the rock surface by forming new compounds. Infiltration : A portion of the precipitation which reaches the earth surface seeps into the ground in the permeable strata. This process is known as infiltration. Insolation : Incoming solar radiation in short wave form. Inter Tropical Convergence Zone (ITCZ) : Zone of low atmospheric pressure and ascending air located at or near the equator. Rising air currents are due to global wind convergence and convection from thermal heating. Katabatic Wind : Any wind blowing down the slope of a mountain. Land Breeze : Local thermal circulation pattern found at the interface between land and water. In this circulation system, surface winds blow from land to water during the night. La Nina : Condition opposite of an El Nino. In a La Nina, the tropical Pacific trade winds become very strong and an abnormal accumulation of cold water occurs in the central and eastern Pacific Ocean. Latent Heat : It is the energy required to change a substance to a higher state of matter (solid > liquid > gas). This same energy is released from the substance when the change of state is reversed (gas > liquid > solid). Neap Tide : Tide that occurs every 14 - 15 days and coincides with the first and last quarter of the moon. This tide has a small tidal range because the gravitational forces of the moon and sun are perpendicular to each other. Rationalised-2023-24 124 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Nimbostratus Clouds : Dark, gray low altitude cloud that produces continuous precipitation in the form of rain or snow. Found in an altitude range from the surface to 3,000 m. Occluded Front : A transition zone in the atmosphere where an advancing cold air mass sandwiches a warm air mass between another cold air mass pushing the warm air into the upper atmosphere. Ozone : Tri-atomic oxygen that exists in the earth's atmosphere as a gas. Ozone is highest in concentration in the stratosphere (10-50 km above the earth's surface) where it absorbs the sun's ultraviolet radiation. Stratospheric ozone is produced naturally and helps to protect life from the harmful effects of solar ultraviolet radiation. Ozone Hole : It is a sharp seasonal decrease in stratospheric ozone concentration that occurs over Antarctica in the spring. First detected in the late 1970s, the ozone hole continues to appear as a result of complex chemical reaction in the atmosphere that involves CFCs. Palaeomagnetism : The alignment in terms of inclination from horizon acquired by magnetically susceptible minerals in the rock during the period of their formation. Photosynthesis : It is the chemical process where plants and some bacteria can capture and organically fix the energy of the sun. Plate Tectonics : Theory suggesting that the earth's surface is composed of a number of oceanic and continental plates. Driven by convection currents in the mantle, these plates have the ability to slowly move across the earth's plastic asthenosphere. Precipitation : Showering of the raindrops, snow or hailstones from the clouds onto the surface of the earth. Rainfall, snowfall, cloud burst and hailstones are forms of precipitation. Runoff : It is the flow of water over land through different channels. Solar Wind : Mass of ionised gas emitted to space by the sun. Plays a role in the formation of auroras. Subsurface flow : It is the movement of water below the surface of the earth. After infiltration, the subsurface water returns to the surface through seepage into the streams or eventually goes into the ocean. The subsurface water flow is influenced by land slope, rainfall, intensity of groundwater extraction, etc. Thermocline : Boundary in a body of water where the greatest vertical change in temperature occurs. This boundary is usually the transition zone between the layer of warm water near the surface that is mixed and the cold deep water layer. Rationalised-2023-24 NOTES Rationalised-2023-24 NOTES Rationalised-2023-24FUNDAMENTALS OF PHYSICAL GEOGRAPHY TEXTBOOK FOR CLASS XI Rationalised-2023-24 

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guiding the work of this committee. Several teachers contributed to the development of this textbook; we are grateful to their principals for making this possible. We are indebted to the institutions and organisations Rationalised-2023-24 which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairpersonship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution. As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement. Director New Delhi National Council of Educational 20 December 2005 Research and Training iv Rationalised-2023-24 RATIONALISATION OF CONTENT IN THE TEXTBOOKS In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, the NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise. Contents of the textbooks have been rationalised in view of the following: · Overlapping with similar content included in other subject areas in the same class · Similar content included in the lower or higher class in the same subject · Difficulty level · Content, which is easily accessible to students without much interventions from teachers and can be learned by children through self-learning or peer-learning · Content, which is irrelevant in the present context This present edition, is a reformatted version after carrying out the changes given above. Rationalised-2023-24 Rationalised-2023-24 TEXTBOOK DEVELOPMENT COMMITTEE CHAIRPERSON, ADVISORY COMMITTEE FOR TEXTBOOKS IN SOCIAL SCIENCES AT THE HIGHER SECONDARY LEVEL Hari Vasudevan, Professor, Department of History, University of Calcutta, Kolkata CHIEF ADVISOR M. H. Qureshi, Professor, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi MEMBERS Indu Sharma, PGT, Geography, RIE Demonstration School, Ajmer K.Kumaraswamy, Professor, Department of Geography, Bharatidasan University, Tiruchirapalli K. N. Prudhvi Raju, Professor, Department of Geography, Banaras Hindu University, Varanasi K. S. Sivasami, Professor (Retd.), Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi L. Cajee, Reader, Department of Geography, North-Eastern Hill University, Shillong P. K. Malik, Lecturer, Geography, Govt. College, Tavru, Gurgaon S. R. Jog, Professor (Retd.), Department of Geography, University of Pune, Pune MEMBER-COORDINATOR Aparna Pandey, Lecturer, Geography, DESSH, NCERT, New Delhi Rationalised-2023-24 ACKNOWLEDGEMENTS The National Council of Educational Research and Training acknowledges the contribution of Ashok Diwakar, Lecturer, Geography, Govt. College, Sector-9, Gurgaon in the development of this textbook. The Council also gratefully acknowledges the support of individuals and organisations as listed below for providing various photographs, and other materials such as articles used in this textbook : R. Vaidyanadhan (Fig. 5.3 and 6.1); N. S. Saini (Fig. 5.4, 5.7 and 6.4); Y. Ramesh and Krishnam Raju, VSVG, (USA) (Fig. 6.11); K.N. Prudhvi Raju (Fig. 6.2, 6.5, 6.7, 6.9, 6.12 and 6.15); ITDC/Ministry of Tourism, Govt. of India, (Fig. 11.1 and 11.2); Ministry of Environment and Forests, Govt. of India (Fig. 14.1, 14.2, 14.3); The Times of India, New Delhi (Photograph on earthquake destruction, Collage on tsunami on page 25 and global warming on page 109); Social Science Textbook for Class VIII, Part II (NCERT, 2005), (Photographs related to volcanoes on page 26-27). Acknowledgements are due to Savita Sinha, Professor and Head, Department of Education in Social Sciences and Humanties for her support and finalising this textbook. The Council also gratefully acknowledges the contributions of Ishwar Singh and Arvind Sharma, DTP Operators; Sameer Khatana and Amar Kumar Prusty, Copy Editors; Bharat Sanwaria, Proof Reader; Dinesh Kumar, Computer Incharge, who have helped in giving a final shape to this book. The contribution of the Publication Department, NCERT are also duly acknowledged.

Rationalised-2023-24 CONTENTS FOREWORD iii UNIT I : GEOGRAPHY AS A DISCIPLINE 1-12 1. Geography as a Discipline 2 UNIT II : THE EARTH 12-35 2. The Origin and Evolution of the Earth 13 3. Interior of the Earth 18 4. Distribution of Oceans and Continents 27 UNIT III : LANDFORMS 36-62 5. Geomorphic Processes 37 6. Landforms and their Evolution 47 UNIT IV : CLIMATE 63-98 7. Composition and Structure of Atmosphere 64 8. Solar Radiation, Heat Balance and Temperature 67 9. Atmospheric Circulation and Weather Systems 76 10. Water in the Atmosphere 86 11. World Climate and Climate Change 91 UNIT V : WATER (OCEANS) 99-113 12. Water (Oceans) 99 13. Movements of Ocean Water 108 UNIT VI : LIFE ON THE EARTH 114-120 14. Biodiversity and Conservation 115 GLOSSARY 121-124 Rationalised-2023-24 CONSTITUTION OF INDIA Part III (Articles 12 – 35) (Subject to certain conditions, some exceptions and reasonable restrictions) guarantees these Fundamental Rights Right to Equality • before law and equal protection of laws; • irrespective of religion, race, caste, sex or place of birth; • of opportunity in public employment; • by abolition of untouchability and titles. Right to Freedom • of expression, assembly, association, movement, residence and profession; • of certain protections in respect of conviction for offences; • of protection of life and personal liberty; • of free and compulsory education for children between the age of six and fourteen years; • of protection against arrest and detention in certain cases. Right against Exploitation • for prohibition of traffic in human beings and forced labour; • for prohibition of employment of children in hazardous jobs. Right to Freedom of Religion • freedom of conscience and free profession, practice and propagation of religion; • freedom to manage religious affairs; • freedom as to payment of taxes for promotion of any particular religion; • freedom as to attendance at religious instruction or religious worship in educational institutions wholly maintained by the State. Cultural and Educational Rights • for protection of interests of minorities to conserve their language, script and culture; • for minorities to establish and administer educational institutions of their choice. Right to Constitutional Remedies • by issuance of directions or orders or writs by the Supreme Court and High Courts for enforcement of these Fundamental Rights. Rationalised-2023-24GEOGRAPHY AS A DISCIPLINE This unit deals with • Geography as an integrating discipline; as a science of spatial attributes • Branches of geography; importance of physical geography UNIT I Rationalised-2023-24 Y ou have studied geography as one of the components of your Social Science course upto the secondary stage. You are already aware of some of the phenomena of geographical nature in the world and its different parts. Now, you will study ‘Geography’ as an independent subject and learn about the physical environment of the earth, human activities and their interactive relationships. Therefore, a pertinent question you can ask at this stage is — Why should we study geography? We live on the surface of the earth. Our lives are affected by our surroundings in many ways. We depend on the resources to sustain ourselves in the surrounding areas. Primitive societies subsisted on ‘natural means of subsistence’, i.e. edible plants and animals. With the passage of time, we developed technologies and started producing our food using natural resources such as land, soil and water. We adjusted our food habits and clothing according to the prevailing weather conditions. There are variations in the natural resource base, technological development, adaptation with and modification of physical environment, social organisations and cultural development. As a student of geography, you should be curious to know about all the phenomena which vary over space. You learn about the diverse lands and people. You should also be interested in understanding the changes which have taken place over time. Geography equips you to appreciate diversity and investigate into the causes responsible for creating such variations over time and space. You will develop skills to understand the globe converted into maps and have a visual sense of the earth’s surface. The understanding and the skills obtained in modern scientific techniques such as GIS and computer cartography equip you to meaningfully contribute to the national endeavour for development. Now the next question which you may like to ask is — What is geography? You know that earth is our home. It is also the home of many other creatures, big and small, which live on the earth and sustain.

The earth's surface is not uniform. It has variations in its physical features. There are mountains, hills, valleys, plains, plateaus, oceans, lakes, deserts and wilderness. There are variations in its social and cultural features too. There are villages, cities, roads, railways, ports, markets and many other elements created by human beings across the entire period of their cultural development. This variation provides a clue to the understanding of the relationship between the physical environment and social/cultural features. The physical environment has provided the stage, on which human societies enacted the drama of their creative skills with the tools and techniques which they invented and evolved in the process of their cultural development. Now, you should be able to attempt the answer of the question posed earlier as to "What is geography"? In very simple words, it can be said that geography is the description of the earth. The term geography was first coined by Eratosthenese, a Greek scholar (276-194 BC.). The word has been derived from two roots from Greek language geo (earth) and graphos (description). GEOGRAPHY AS A DISCIPLINE CHAPTER Rationalised-2023-24 GEOGRAPHY AS A DISCIPLINE 3 Put together, they mean description of the earth. The earth has always been seen as the abode of human beings and thus, scholars defined geography as, "the description of the earth as the abode of human beings". You are aware of the fact that reality is always multifaceted and the 'earth' is also multi-dimensional, that is why many disciplines from natural sciences such as geology, pedology, oceanography, botany, zoology and meteorology and a number of sister disciplines in social sciences such as economics, history, sociology, political science, anthropology, etc. study different aspects of the earth's surface. Geography is different from other sciences in its subject matter and methodology but at the same time, it is closely related to other disciplines. Geography derives its data base from all the natural and social sciences and attempts their synthesis. We have noted that there exist variations over the surface of the earth in its physical as well as cultural environment. A number of phenomena are similar and many are dissimilar. It was, therefore, logical to perceive geography as the study of areal differentiation. Thus, geography was perceived to study all those phenomena which vary over space. Geographers do not study only the variations in the phenomena over the earth's surface (space) but also study the associations with the other factors which cause these variations. For example, cropping patterns differ from region to region but this variation in cropping pattern, as a phenomenon, is related to variations in soils, climates, demands in the market, capacity of the farmer to invest and technological inputs available to her/him. Thus, the concern of geography is to find out the causal relationship between any two phenomena or between more than one phenomenon. A geographer explains the phenomena in a frame of cause and effect relationship, as it does not only help in interpretation but also foresees the phenomena in future. The geographical phenomena, both the physical and human, are not static but highly dynamic. They change over time as a result of the interactive processes between ever changing earth and untiring and ever-active human beings. Primitive human societies were directly dependent on their immediate environment. Geography, thus, is concerned with the study of Nature and Human interactions as an integrated whole. 'Human' is an integral part of 'nature' and 'nature' has the imprints of 'human'. 'Nature' has influenced different aspects of human life. Its imprints can be noticed on food, clothing, shelter and occupation. Human beings have come to terms with nature through adaptation and modification. As you already know, the present society has passed the stage of primitive societies, which were directly dependent on their immediate physical environment for sustenance. Present societies have modified their natural environment by inventing and using technology and thus, have expanded the horizon of their operation by appropriating and utilising the resources provided by nature. With the gradual development of technology, human beings were able to loosen the shackles of their physical environment. Technology helped in reducing the harshness of labour, increased labour efficiency and provided leisure to human beings to attend to the higher needs of life. It also increased the scale of production and the mobility of labour. The interaction between the physical environment and human beings has been very succinctly described by a poet in

the following dialogue between ‘human’ and ‘nature’ (God). You created the soil, I created the cup, you created night, I created the lamp. You created wilderness, hilly terrains and deserts; I created flower beds and gardens. Human beings have claimed their contribution using natural resources. With the help of technology, human beings moved from the stage of necessity to a stage of freedom. They have put their imprints everywhere and created new possibilities in collaboration with nature. Thus, we now find humanised nature and naturalised human beings and geography studies this interactive relationship. The space got organised with the help of the means of transportation and communication network. The links (routes) and nodes (settlements of all types and hierarchies) integrated the space and Rationalised-2023-24 4 FUNDAMENTALS OF PHYSICAL GEOGRAPHY gradually, it got organised. As a social science discipline, geography studies the ‘spatial organisation’ and ‘spatial integration’. Geography as a discipline is concerned with three sets of questions: (i) Some questions are related to the identification of the patterns of natural and cultural features as found over the surface of the earth. These are the questions about what? (ii) Some questions are related to the distribution of the natural and human/ cultural features over the surface of the earth. These are the questions about where? Taken together, both these questions take care of distributional and locational aspects of the natural and cultural features. These questions provided inventorised information of what features and where located. It was a very popular approach during the colonial period. These two questions did not make geography a scientific discipline till the third question was added. (iii) The third question is related to the explanation or the causal relationships between features and the processes and phenomena. This aspect of geography is related to the question, why? Geography as a discipline is related to space and takes note of spatial characteristics and attributes. It studies the patterns of distribution, location and concentration of phenomena over space and interprets them providing explanations for these patterns. It takes note of the associations and inter - relationships between the phenomena over space and interprets them providing explanations for these patterns. It also takes note of the associations and inter-relationships between the phenomena resulting from the dynamic interaction between human beings and their physical environment. GEOGRAPHY AS AN INTEGRATING DISCIPLINE Geography is a discipline of synthesis. It attempts spatial synthesis, and history attempts temporal synthesis. Its approach is holistic in nature. It recognises the fact that the world is a system of interdependencies. The present world is being perceived as a global village. The distances have been reduced by better means of transportation increasing accessibility. The audio-visual media and information technology have enriched the data base. Technology has provided better chances of monitoring natural phenomena as well as the economic and social parameters. Geography as an integrating discipline has interface with numerous natural and social sciences. All the sciences, whether natural or social, have one basic objective, of understanding the reality. Geography attempts to comprehend the associations of phenomena as related in sections of reality. Figure 1.1 shows the relationship of geography with other sciences. Every discipline, concerned with scientific knowledge is linked with geography as many of their elements vary over space. Geography helps in understanding the reality in totality in its spatial perspective. Geography, thus, not only takes note of the differences in the phenomena from place to place but integrates them holistically which may be different at other places. A geographer is required to have a broad understanding of all the related fields, to be able to logically integrate them. This integration can be understood with some examples. Geography influences historical events. Spatial distance itself has been a very potent factor to alter the course of history of the world. Spatial depth provided defence to many countries, particularly in the last century. In traditional warfare, countries with large size in area, gain time at the cost of space. The defence provided by oceanic expanse around the countries of the new world has protected them from wars being imposed on their soil. If we look at the historical events world over, each one of them can be interpreted geographically. In India, Himalayas have acted as great barriers and provided protection

but the passes provided routes to the migrants and invaders from Central Asia. The sea coast has encouraged contact with people from East and Southeast Asia, Europe and Africa. Navigation technology helped European countries to colonise a number of countries of Asia and Africa, including India as they got accessibility Rationalised-2023-24 GEOGRAPHY AS A DISCIPLINE 5 FIELD OF GEOGRAPHY Figure 1.1 : Geography and its relation with other disciplines Rationalised-2023-24 6 FUNDAMENTALS OF PHYSICAL GEOGRAPHY through oceans. The geographical factors have modified the course of history in different parts of the world. Every geographical phenomenon undergoes change through time and can be explained temporally. The changes in landforms, climate, vegetation, economic activities occupations and cultural developments have followed a definite historical course. Many geographical features result from the decision making process by different institutions at a particular point of time. It is possible to convert time in terms of space and space in terms of time. For example, it can be said that place A is 1,500 km from place B or alternately, it can also be said that place A is two hours away (if one travels by plane) or seventeen hours away (if one travels by a fast moving train). It is for this reason, time is an integral part of geographical studies as the fourth dimension. Please mention other three dimensions? Figure1.1 amply depicts the linkages of geography with different natural and social sciences. This linkage can be put under two segments. BRANCHES OF GEOGRAPHY Please study Figure 1.1 for recapitulation. It has very clearly brought out that geography is an interdisciplinary subject of study. The study of every subject is done according to some approach. The major approaches to study geography have been (i) Systematic and (ii) Regional. The systematic geography approach is the same as that of general geography. This approach was introduced by Alexander Von Humboldt, a German geographer (1769-1859) while regional geography approach was developed by another German geographer and a contemporary of Humboldt, Karl Ritter (1779-1859). In systematic approach (Figure 1.2), a phenomenon is studied world over as a whole, and then the identification of typologies or spatial patterns is done. For example, if one is interested in studying natural vegetation, the study will be done at the world level as a first step. The typologies such as equatorial rain forests or softwood conical forests or monsoon forests, etc. will be identified, discussed and delimited. In the regional approach, the world is divided into regions at different hierarchical levels and then all the geographical phenomena in a particular region are studied. These regions may be natural, political or designated region. The phenomena in a region are studied in a holistic manner searching for unity in diversity. Dualism is one of the main characteristics of geography which got introduced from the very beginning. This dualism depended on the aspect emphasised in the study. Earlier scholars laid emphasis on physical geography. But human beings are an integral part of the earth’s surface. They are part and parcel of nature. They also have contributed through their cultural development. Thus developed human geography with emphasis on human activities. BRANCHES OF GEOGRAPHY (BASED ON SYSTEMATIC APPROACH) 1. Physical Geography (i) Geomorphology is devoted to the study of landforms, their evolution and related processes. (ii) Climatology encompasses the study of structure of atmosphere and elements of weather and climates and climatic types and regions. (iii) Hydrology studies the realm of water over the surface of the earth including oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities. (iv) Soil Geography is devoted to study the processes of soil formation, soil types, their fertility status, distribution and use. 2. Human Geography (i) Social/Cultural Geography encompasses the study of society and its spatial dynamics as well as the cultural elements contributed by the society. Rationalised-2023-24 GEOGRAPHY AS A DISCIPLINE 7 Figure 1.2 : Branches of geography based on systematic approach (ii) Population and Settlement Geography (Rural and Urban). It studies population growth, distribution, density, sex ratio, migration and occupational structure etc. Settlement geography studies the characteristics of rural and urban settlements. (iii) Economic Geography studies economic activities of the people including agriculture, industry, tourism, trade, and transport, infrastructure and services, etc. (iv)

Historical Geography studies the historical processes through which the space gets organised. Every region has undergone some historical experiences before attaining the present day status. The geographical features also Rationalised-2023-24 8 FUNDAMENTALS OF PHYSICAL GEOGRAPHY experience temporal changes and these form the concerns of historical gography. (v) Political Geography looks at the space from the angle of political events and studies boundaries, space relations between neighbouring political units, delimitation of constituencies, election scenario and develops theoretical framework to understand the political behaviour of the population. 3. Biogeography The interface between physical geography and human geography has lead to the development of Biogeography which includes: (i) Plant Geography which studies the spatial pattern of natural vegetation in their habitats. (ii) Zoo Geography which studies the spatial patterns and geographic characteristics of animals and their habitats. (iii) Ecology /Ecosystem deals with the scientific study of the habitats characteristic of species. (iv) Environmental Geography concerns world over leading to the realisation of environmental problems such as land gradation, pollution and concerns for conservation has resulted in the introduction of this new branch in geography. BRANCHES OF GEOGRAPHY BASED ON REGIONAL APPROACH (FIGURE1.3) 1. Regional Studies/Area Studies Comprising Macro, Meso and Micro Regional Studies 2. Regional Planning Comprising Country/Rural and Town/ Urban Planning 3. Regional Development 4. Regional Analysis There are two aspects which are common to every discipline, these are: (i) Philosophy (a) Geographical Thought (b) Land and Human Interaction/ Human Ecology (ii) Methods and Techniques (a) Cartography including Computer Cartography (b) Quantitative Techniques/Statistical Techniques (c) Field Survey Methods (d) Geo-informatics comprising techniques such as Remote Sensing, GIS, GPS, etc. The above classification gives a comprehensive format of the branches of geography. Generally geography curricula is taught and learnt in this format but this format is not static. Any discipline is bound to grow with new ideas, problems, methods and techniques. For example, what was once manual cartography has now been Figure 1.3 : Branches of geography based on regional approach Rationalised-2023-24 GEOGRAPHY AS A DISCIPLINE 9 What is Geography? Geography is concerned with the description and explanation of the areal differentiation of the earth's surface. Richard Hartshorne Geography studies the differences of phenomena usually related in different parts of the earth's surface. Hettner transformed into computer cartography. Technology has enabled scholars to handle large quantum of data. The internet provides extensive information. Thus, the capacity to attempt analysis has increased tremendously. GIS has further opened vistas of knowledge. GPS has become a handy tool to find out exact locations. Technologies have enhanced the capacity of attempting synthesis with sound theoretical understanding. You will learn some preliminary aspects of these techniques in your book, Practical work in Geography – Part I (NCERT, 2006). You will continue to improve upon your skills and learn about their application. PHYSICAL GEOGRAPHY AND ITS IMPORTANCE This chapter appears in the book entitled Fundamentals of Physical Geography. The contents of the book clearly reflect its scope. It is therefore, appropriate to know the importance of this branch of geography. Physical geography includes the study of lithosphere (landforms, drainage, relief and physiography), atmosphere (its composition, structure, elements and controls of weather and climate; temperature, pressure, winds, precipitation, climatic types, etc.), hydrosphere (oceans, seas, lakes and associated features with water realm) and biosphere ( life forms including human being and macro-organism and their sustaining mechanism, viz. food chain, ecological parameters and ecological balance). Soils are formed through the process of pedogenesis and depend upon the parent rocks, climate, biological activity and time. Time provides maturity to soils and helps in the development of soil profiles. Each element is important for human beings. Landforms provide the base on which human activities are located. The plains are utilised for agriculture. Plateaus provide forests and minerals. Mountains provide pastures, forests, tourist spots and are sources of rivers providing water to lowlands. Climate influences our house types, clothing and food habits. The

climate has a profound effect on vegetation, cropping pattern, livestock farming and some industries, etc. Human beings have developed technologies which modify climatic elements in a restricted space such as air conditioners and coolers. Temperature and precipitation ensure the density of forests and quality of grassland. In India, monsoonal rainfall sets the agriculture rhythm in motion. Precipitation recharges the ground water aquifers which later provides water for agriculture and domestic use. We study oceans which are the store house of resources. Besides fish and other sea-food, oceans are rich in mineral resources. India has developed the technology for collecting manganese nodules from oceanic bed. Soils are renewable resources, which influence a number of economic activities such as agriculture. The fertility of the soil is both naturally determined and culturally induced. Soils also provide the basis for the biosphere accommodating plants, animals and micro organisms. The study of physical geography is emerging as a discipline of evaluating and managing natural resources. In order to achieve this objective, it is essential to understand the intricate relationship between physical environment and human beings. Physical environment provides resources, and human beings utilise these resources and ensure their economic and cultural development. Accelerated pace of resource utilisation with the help of modern technology has created ecological imbalance in the world. Hence, a better understanding of physical environment is absolutely essential for sustainable development. Rationalised-2023-24 10 FUNDAMENTALS OF PHYSICAL GEOGRAPHY EXERCISES 1. Multiple choice questions. (i) Which one of the following scholars coined the term 'Geography'? (a) Herodotus (c) Galileo (b) Erathosthenese (d) Aristotle (ii) Which one of the following features can be termed as 'physical feature'? (a) Port (c) Plain (b) Road (d) Water park (iii) Make correct pairs from the following two columns and mark the correct option. 1. Meteorology A. Population Geography 2. Demography B. Soil Geography 3. Sociology C. Climatology 4. Pedology D. Social Geography (a) 1B,2C,3A,4D (c) 1D,2B,3C,4A (b) 1A,2D,3B,4C (d) 1C,2A,3D,4B (iv) Which one of the following questions is related to cause-effect relationship? (a) Why (c) What (b) Where (d) When (v) Which one of the following disciplines attempts temporal synthesis? (a) Sociology (c) Anthropology (b) Geography (d) History 2. Answer the following questions in about 30 words. (i) What important cultural features do you observe while going to school? Are they similar or dissimilar? Should they be included in the study of geography or not? If yes, why? (ii) You have seen a tennis ball, a cricket ball, an orange and a pumpkin. Which one amongst these resembles the shape of the earth? Why have you chosen this particular item to describe the shape of the earth? (iii) Do you celebrate Van Mahotsava in your school? Why do we plant so many trees? How do the trees maintain ecological balance? (iv) You have seen elephants, deer, earthworms, trees and grasses. Where do they live or grow? What is the name given to this sphere? Can you describe some of the important features of this sphere? (v) How much time do you take to reach your school from your house? Had the school been located across the road from your house, how much time would you have taken to reach school? What is the effect of the distance Rationalised-2023-24 GEOGRAPHY AS A DISCIPLINE 11 between your residence and the school on the time taken in commuting? Can you convert time into space and vice versa? 3. Answer the following questions in about 150 words. (i) You observe every day in your surroundings that there is variation in natural as well as cultural phenomena. All the trees are not of the same variety. All the birds and animals you see, are different. All these different elements are found on the earth. Can you now argue that geography is the study of "areal differentiation"? (ii) You have already studied geography, history, civics and economics as parts of social studies. Attempt an integration of these disciplines highlighting their interface. Project Work Select forest as a natural resource. (i) Prepare a map of India showing the distribution of different types of forests. (ii) Write about the economic importance of forests for the country. (iii) Prepare a historical account of conservation of forests in India with focus on Chipko movements in Rajasthan and Uttaranchal. Rationalised-2023-2412 FUNDAMENTALS OF PHYSICAL GEOGRAPHY THE EARTH This unit deals with • Origin and evolution of the earth; Interior of the earth; Wegener's

continental drift theory and plate tectonics; earthquakes and volcanoes UNIT II Rationalised-2023-24 D o you remember the nursery rhyme "…Twinkle, twinkle little star…"? Starry nights have always attracted us since the childhood. You may also have thought of these stars and had numerous questions in your mind. Questions such as how many stars are there in the sky? How did they come into existence? Can one reach the end of the sky? May be many more such questions are still there in your mind. In this chapter, you will learn how these "twinkling little stars" were formed. With that you will eventually also read the story of origin and evolution of the earth. EARLY THEORIES Origin of the Earth A large number of hypotheses were put forth by different philosophers and scientists regarding the origin of the earth. One of the earlier and popular arguments was by German philosopher Immanuel Kant. Mathematician Laplace revised it in 1796. It is known as Nebular Hypothesis. The hypothesis considered that the planets were formed out of a cloud of material associated with a youthful sun, which was slowly rotating. In 1950, Otto Schmidt in Russia and Carl Weizascar in Germany somewhat revised the 'nebular hypothesis', though differing in details. They considered that the sun was surrounded by solar nebula containing mostly the hydrogen and helium along with what may be termed as dust. The friction and collision of particles led to formation of a disk-shaped cloud and the planets were THE ORIGIN AND EVOLUTION OF THE EARTH CHAPTER formed through the process of accretion. However, scientists in later period took up the problems of origin of universe rather than that of just the earth or the planets. MODERN THEORIES Origin of the Universe The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called expanding universe hypothesis. Edwin Hubble, in 1920, provided evidence that the universe is expanding. As time passes, galaxies move further and further apart. You can experiment and find what does the expanding universe mean. Take a balloon and mark some points on it to represent the galaxies. Now, if you start inflating the balloon, the points marked on the balloon will appear to be moving away from each other as the balloon expands. Similarly, the distance between the galaxies is also found to be increasing and thereby, the universe is considered to be expanding. However, you will find that besides the increase in the distances between the points on the balloon, the points themselves are expanding. This is not in accordance with the fact. Scientists believe that though the space between the galaxies is increasing, observations do not support the expansion of galaxies. So, the balloon example is only partially correct. The Big Bang Theory considers the following stages in the development of the universe. (i) In the beginning, all matter forming the universe existed in one place in the form of a "tiny ball" (singular atom) with an Rationalised-2023-24 14 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Figure 2.1 : The Big Bang unimaginably small volume, infinite temperature and infinite density. (ii) At the Big Bang the "tiny ball" exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form. (iii) Within 300,000 years from the Big Bang, temperature dropped to 4,500K (Kelvin) and gave rise to atomic matter. The universe became transparent. The expansion of universe means increase in space between the galaxies. An alternative to this was Hoyle's concept of steady state. It considered the universe to be roughly the same at any point of time. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe. The Star Formation The distribution of matter and energy was not even in the early universe. These initial density differences gave rise to differences in gravitational forces and it caused the matter to get drawn together. These formed the bases for development of galaxies. A galaxy contains a large number of stars. Galaxies spread over vast distances that are measured in thousands of light-years. The diameters of individual galaxies range from 80,000-150,000 light years. A galaxy starts to form by accumulation of hydrogen

gas in the form of a very large cloud called nebula. Eventually, growing nebula develops localised clumps of gas. These clumps continue to grow into even denser gaseous bodies, giving rise to formation of stars. The formation of stars is believed to have taken place some 5-6 billion years ago. A light year is a measure of distance and not of time. Light travels at a speed of 300,000 km/second. Considering this, the distances the light will travel in one year is taken to be one light year. This equals to 9.461×1012 km. The mean distance between the sun and the earth is 149,598,000 km. In terms of light years, it is 8.311minutes. Formation of Planets The following are considered to be the stages in the development of planets : (i) The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core to the gas cloud and a huge rotating disc of gas and dust develops around the gas core. Singularity Rationalised-2023-24 THE ORIGIN AND EVOLUTION OF THE EARTH 15 (ii) In the next stage, the gas cloud starts getting condensed and the matter around the core develops into smallrounded objects. These small-rounded objects by the process of cohesion develop into what is called planetesimals. Larger bodies start forming by collision, and gravitational attraction causes the material to stick together. Planetesimals are a large number of smaller bodies. (iii) In the final stage, these large number of small planetesimals accrete to form a fewer large bodies in the form of planets. EVOLUTION OF THE EARTH Do you know that the planet earth initially was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium. This is far from the present day picture of the earth. Hence, there must have been some events– processes, which may have caused this change from rocky, barren and hot earth to a beautiful planet with ample amount of water and conducive atmosphere favouring the existence of life. In the following section, you will find out how the period, between the 4,600 million years and the present, led to the evolution of life on the surface of the planet. The earth has a layered structure. From the outermost end of the atmosphere to the centre of the earth, the material that exists is not uniform. The atmospheric matter has the least density. From the surface to deeper depths, the earth's interior has different zones and each of these contains materials with different characteristics. How was the layered structure of the earth developed? Evolution of Lithosphere The earth was mostly in a volatile state during its primordial stage. Due to gradual increase in density the temperature inside has increased. As a result the material inside started getting separated depending on their densities. This allowed heavier materials (like iron) to sink towards the centre of the earth and the lighter ones to move towards the surface. With passage of time it cooled further and solidified and condensed into a smaller size. This later led to the development of the outer surface in the form of a crust. During the formation of the moon, due to the giant impact, the earth was further heated up. It is through the process of differentiation that the earth forming material got separated into different layers. Starting from the surface to the central parts, we have layers like the crust, mantle, outer core and inner core. From the crust to the core, the density of the material increases. We shall discuss in detail the properties of each of this layer in the next chapter. Evolution of Atmosphere and Hydrosphere The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen. You will be dealing with the composition and structure of the earth's atmosphere in Chapter 8. There are three stages in the evolution of the present atmosphere. The first stage is marked by the loss of primordial atmosphere. In the second stage, the hot interior of the earth contributed to the evolution of the atmosphere. Finally, the composition of the atmosphere was modified by the living world through the process of photosynthesis. The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds. This happened not only in case of the earth, but also in all the terrestrial planets, which were supposed to have lost their primordial atmosphere through the impact of solar winds. During the cooling of the earth, gases and water vapour were released from the interior solid earth. This started the evolution of the present atmosphere. The early atmosphere largely contained water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free

oxygen. The process through which the gases were outpoured from the interior is called degassing. Continuous volcanic eruptions contributed water vapour and gases to the atmosphere. As the earth cooled, the water vapour released started getting Rationalised-2023-24 16 FUNDAMENTALS OF PHYSICAL GEOGRAPHY condensed. The carbon dioxide in the atmosphere got dissolved in rainwater and the temperature further decreased causing more condensation and more rains. The rainwater falling onto the surface got collected in the depressions to give rise to oceans. The earth's oceans were formed within 500 million years from the formation of the earth. This tells us that the oceans are as old as 4,000 million years. Sometime around 3,800 million years ago, life began to evolve. However, around 2,500-3,000 million years before the present, the process of photosynthesis got evolved. Life was confined to the oceans for a long time. Oceans began to have the contribution of oxygen through the process of photosynthesis. Eventually, oceans were saturated with oxygen, and 2,000 million years ago, oxygen began to flood the atmosphere. Origin of Life The last phase in the evolution of the earth relates to the origin and evolution of life. It is undoubtedly clear that initially the earth or even the atmosphere of the earth was not conducive for the development of life. Modern scientists refer to the origin of life as a kind of chemical reaction, which first generated complex organic molecules and assembled them. This assemblage was such that they could duplicate themselves converting inanimate matter into living substance. The record of life that existed on this planet in different periods is found in rocks in the form of fossils. The microscopic structures closely related to the present form of blue algae have been found in geological formations much older than some 3,000 million years. It can be assumed that life began to evolve sometime 3,800 million years ago. The summary of evolution of life from unicellular bacteria to the modern man is given in the Geological Time Scale on page 18. EXERCISES 1. Multiple choice questions. (i) Which one of the following figures represents the age of the earth? (a) 4.6 million years (c) 4.6 billion years (b) 13.7 billion years (d) 13.7 trillion years (ii) Which one of the following is not related to the formation or modification of the present atmosphere? (a) Solar winds (c) Degassing (b) Differentiation (d) Photosynthesis (iii) Life on the earth appeared around how many years before the present? (a) 13.7 billion (c) 4.6 billion (b) 3.8 million (d) 3.8 billion 2. Answer the following questions in about 30 words. (i) What is meant by the process of differentiation? (ii) What was the nature of the earth surface initially? (iii) What were the gases which initially formed the earth's atmosphere? Rationalised-2023-24 THE ORIGIN AND EVOLUTION OF THE EARTH 17 3. Answer the following questions in about 150 words. (i) Write an explanatory note on the 'Big Bang Theory'. (ii) List the stages in the evolution of the earth and explain each stage in brief. Project Work Collect information about the project "Stardust" (website: www.sci.edu/public.html and www.nasm.edu) along the following lines. (i) Which is the agency that has launched this project? (ii) Why are scientists interested in collecting Stardust? (iii) Where from the Stardust is being collected? Rationalised-2023-2418 FUNDAMENTALS OF PHYSICAL GEOGRAPHY W hat do you imagine about the nature of the earth? Do you imagine it to be a solid ball like cricket ball or a hollow ball with a thick cover of rocks i.e. lithosphere? Have you ever seen photographs or images of a volcanic eruption on the television screen? Can you recollect the emergence of hot molten lava, dust, smoke, fire and magma flowing out of the volcanic crater? The interior of the earth can be understood only by indirect evidences as neither any one has nor any one can reach the interior of the earth. The configuration of the surface of the earth is largely a product of the processes operating in the interior of the earth. Exogenic as well as endogenic processes are constantly shaping the landscape. A proper understanding of the physiographic character of a region remains incomplete if the effects of endogenic processes are ignored. Human life is largely influenced by the physiography of the region. Therefore, it is necessary that one gets acquainted with the forces that influence landscape development. To understand why the earth shakes or how a tsunami wave is generated, it is necessary that we know certain details of the interior of the earth. In the previous chapter, you have noted that the earth-forming materials

have been distributed in the form of layers from the crust to the core. It is interesting to know how scientists have gathered information about these layers and what are the characteristics of each of these layers. This is exactly what this chapter deals with. INTERIOR OF THE EARTH SOURCES OF INFORMATION ABOUT THE INTERIOR The earth's radius is 6,370 km. No one can reach the centre of the earth and make observations or collect samples of the material. Under such conditions, you may wonder how scientists tell us about the earth's interior and the type of materials that exist at such depths. Most of our knowledge about the interior of the earth is largely based on estimates and inferences. Yet, a part of the information is obtained through direct observations and analysis of materials. Direct Sources The most easily available solid earth material is surface rock or the rocks we get from mining areas. Gold mines in South Africa are as deep as 3 - 4 km. Going beyond this depth is not possible as it is very hot at this depth. Besides mining, scientists have taken up a number of projects to penetrate deeper depths to explore the conditions in the crustal portions. Scientists world over are working on two major projects such as "Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project". The deepest drill at Kola, in Arctic Ocean, has so far reached a depth of 12 km. This and many deep drilling projects have provided large volume of information through the analysis of materials collected at different depths. Volcanic eruption forms another source of obtaining direct information. As and when the molten material (magma) is thrown onto the surface of the earth, during volcanic eruption it becomes available for laboratory analysis. However, it is difficult to ascertain the depth of the source of such magma. CHAPTER Rationalised-2023-24 INTERIOR OF THE EARTH 19 Indirect Sources Analysis of properties of matter indirectly provides information about the interior. We know through the mining activity that temperature and pressure increase with the increasing distance from the surface towards the interior in deeper depths. Moreover, it is also known that the density of the material also increases with depth. It is possible to find the rate of change of these characteristics. Knowing the total thickness of the earth, scientists have estimated the values of temperature, pressure and the density of materials at different depths. The details of these characteristics with reference to each layer of the interior are discussed later in this chapter. Another source of information are the meteors that at times reach the earth. However, it may be noted that the material that becomes available for analysis from meteors, is not from the interior of the earth. The material and the structure observed in the meteors are similar to that of the earth. They are solid bodies developed out of materials same as, or similar to, our planet. Hence, this becomes yet another source of information about the interior of the earth. The other indirect sources include gravitation, magnetic field, and seismic activity. The gravitation force (g) is not the same at different latitudes on the surface. It is greater near the poles and less at the equator. This is because of the distance from the centre at the equator being greater than that at the poles. The gravity values also differ according to the mass of material. The uneven distribution of mass of material within the earth influences this value. The reading of the gravity at different places is influenced by many other factors. These readings differ from the expected values. Such a difference is called gravity anomaly. Gravity anomalies give us information about the distribution of mass of the material in the crust of the earth. Magnetic surveys also provide information about the distribution of magnetic materials in the crustal portion, and thus, provide information about the distribution of materials in this part. Seismic activity is one of the most important sources of information about the interior of the earth. Hence, we shall discuss it in some detail. Earthquake The study of seismic waves provides a complete picture of the layered interior. An earthquake in simple words is shaking of the earth. It is a natural event. It is caused due to release of energy, which generates waves that travel in all directions. Why does the earth shake? The release of energy occurs along a fault. A fault is a sharp break in the crustal rocks. Rocks along a fault tend to move in opposite directions. As the overlying rock strata press them, the friction locks them together. However, their tendency to move apart at some point of time overcomes the friction. As a result, the blocks get deformed and eventually, they

slide past one another abruptly. This causes a release of energy, and the energy waves travel in all directions. The point where the energy is released is called the focus of an earthquake, alternatively, it is called the hypocentre. The energy waves travelling in different directions reach the surface. The point on the surface, nearest to the focus, is called epicentre. It is the first one to experience the waves. It is a point directly above the focus. Earthquake Waves All natural earthquakes take place in the lithosphere. You will learn about different layers of the earth later in this chapter. It is sufficient to note here that the lithosphere refers to the portion of depth up to 200 km from the surface of the earth. An instrument called 'seismograph' records the waves reaching the surface. A curve of earthquake waves recorded on the seismograph is given in Figure 3.1. Note that the curve shows three distinct sections each representing different types of wave patterns. Earthquake waves are basically of two types — body waves and surface waves. Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. Hence, the name Rationalised-2023-24 20 FUNDAMENTALS OF PHYSICAL GEOGRAPHY body waves. The body waves interact with the surface rocks and generate new set of waves called surface waves. These waves move along the surface. The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities. propagation. As a result, it creates density differences in the material leading to stretching and squeezing of the material. Other three waves vibrate perpendicular to the direction of propagation. The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane. Hence, they create troughs and crests in the material through which they pass. Surface waves are considered to be the most damaging waves. Emergence of Shadow Zone Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves are not reported. Such a zone is called the 'shadow zone'. The study of different events reveals that for each earthquake, there exists an altogether different shadow zone. Figure 3.2 (a) and (b) show the shadow zones of P and S-waves. It was observed that seismographs located at any distance within 105° from the epicentre, recorded the arrival of both P and S-waves. However, the seismographs located beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves. Thus, a zone between 105° and 145° from epicentre was identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-wave is much larger than that of the P-waves. The shadow zone of P-waves appears as a band around the earth between 105° and 145° away from the epicentre. The shadow zone of S-waves is not only larger in extent but it is also a little over 40 per cent of the earth surface. You can draw the shadow zone for any earthquake provided you know the location of the epicentre. (See the activity box on page 28 to know how to locate the epicentre of a quake event). Types of Earthquakes (i) The most common ones are the tectonic earthquakes. These are generated due to sliding of rocks along a fault plane. (ii) A special class of tectonic earthquake is sometimes recognised as volcanic earthquake. However, these are confined to areas of active volcanoes. Figure 3.1 : Earthquake Waves There are two types of body waves. They are called P and S-waves. P-waves move faster and are the first to arrive at the surface. These are also called 'primary waves'. The P-waves are similar to sound waves. They travel through gaseous, liquid and solid materials. S-waves arrive at the surface with some time lag. These are called secondary waves. An important fact about S-waves is that they can travel only through solid materials. This characteristic of the S-waves is quite important. It has helped scientists to understand the structure of the interior of the earth. Reflection causes waves to rebound whereas refraction makes waves move in different directions. The variations in the direction of waves are inferred with the help of their record on seismograph. The surface waves are the last to report on seismograph. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs. Propagation of Earthquake Waves Different types of earthquake waves travel in

different manners. As they move or propagate, they cause vibration in the body of the rocks through which they pass. P-waves vibrate parallel to the direction of the wave. This exerts pressure on the material in the direction of the Rationalised-2023-24 INTERIOR OF THE EARTH 21 (v) The earthquakes that occur in the areas of large reservoirs are referred to as reservoir induced earthquakes. Measuring Earthquakes The earthquake events are scaled either according to the magnitude or intensity of the shock. The magnitude scale is known as the Richter scale. The magnitude relates to the energy released during the quake. The magnitude is expressed in numbers, 0-10. The intensity scale is named after Mercalli, an Italian seismologist. The intensity scale takes into account the visible damage caused by the event. The range of intensity scale is from 1-12. EFFECTS OF EARTHQUAKE Earthquake is a natural hazard. The following are the immediate hazardous effects of earthquake: (i) Ground Shaking (ii) Differential ground settlement (iii) Land and mud slides (iv) Soil liquefaction (v) Ground lurching (vi) Avalanches (vii) Ground displacement (viii) Floods from dam and levee failures (ix) Fires (x) Structural collapse (xi) Falling objects (xii) Tsunami The first six listed above have some bearings upon landforms, while others may be considered the effects causing immediate concern to the life and properties of people in the region. The effect of tsunami would occur only if the epicentre of the tremor is below oceanic waters and the magnitude is sufficiently high. Tsunamis are waves generated by the tremors and not an earthquake in itself. Though the actual quake activity lasts for a few seconds, its effects are devastating provided the magnitude of the quake is more than 5 on the Richter scale. Figure 3.2 (a) and (b) : Earthquake Shadow Zones (iii) In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors. These are called collapse earthquakes. (iv) Ground shaking may also occur due to the explosion of chemical or nuclear devices. Such tremors are called explosion earthquakes. 105 105 105 145 145 105 105 Rationalised-2023-24 22 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Frequency of Earthquake Occurrences The earthquake is a natural hazard. If a tremor of high magnitude takes place, it can cause heavy damage to the life and property of people. However, not all the parts of the globe necessarily experience major shocks. We shall be discussing the distribution of earthquakes and volcanoes with some details in the next once in 1-2 years whereas those of 'tiny' types occur almost every minute. STRUCTURE OF THE EARTH The Crust It is the outermost solid part of the earth. It is brittle in nature. The thickness of the crust varies under the oceanic and continental areas. Oceanic crust is thinner as compared to the continental crust. The mean thickness of oceanic crust is 5 km whereas that of the continental is around 30 km. The continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region. The Mantle The portion of the interior beyond the crust is called the mantle. The mantle extends from Moho's discontinuity to a depth of 2,900 km. The upper portion of the mantle is called asthenosphere. The word astheno means weak. It is considered to be extending upto 400 km. It is the main source of magma that finds chapter. Note that the quakes of high magnitude, i.e. 8+ are quite rare; they occur A view of the damaged Aman Setu at the LOC in Uri, due to an earthquake Rationalised-2023-24 INTERIOR OF THE EARTH 23 its way to the surface during volcanic eruptions. The crust and the uppermost part of the mantle are called lithosphere. Its thickness ranges from 10-200 km. The lower mantle extends beyond the asthenosphere. It is in solid state. The Core As indicated earlier, the earthquake wave velocities helped in understanding the existence of the core of the earth. The coremantle boundary is located at the depth of 2,900 km. The outer core is in liquid state while the inner core is in solid state. The core is made up of very heavy material mostly constituted by nickel and iron. It is sometimes referred to as the nife layer. VOLCANOES AND VOLCANIC LANDFORMS You may have seen photographs or pictures of volcanoes on a number of occasions. A volcano is a place where gases, ashes and/or molten rock material – lava – escape to the ground. A volcano is called an active volcano if the materials mentioned are being released or have been released out in the recent past. The layer below the solid crust is mantle. It has higher density than that of the crust. The

mantle contains a weaker zone called asthenosphere. It is from this that the molten rock materials find their way to the surface. The material in the upper mantle portion is called magma. Once it starts moving towards the crust or it reaches the surface, it is referred to as lava. The material that reaches the ground includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorene, hydrogen and argon. Volcanoes Volcanoes are classified on the basis of nature of eruption and the form developed at the surface. Major types of volcanoes are as follows: Shield Volcanoes Barring the basalt flows, the shield volcanoes are the largest of all the volcanoes on the earth. The Hawaiian volcanoes are the most famous Figure 3.3 : The interior of the earth Shield Volcano Cinder Cone Rationalised-2023-24 24 FUNDAMENTALS OF PHYSICAL GEOGRAPHY examples. These volcanoes are mostly made up of basalt, a type of lava that is very fluid when erupted. For this reason, these volcanoes are not steep. They become explosive if somehow water gets into the vent; otherwise, they are characterised by low-explosivity. The upcoming lava moves in the form of a fountain and throws out the cone at the top of the vent and develops into cinder cone. Composite Volcanoes These volcanoes are characterised by eruptions of cooler and more viscous lavas than basalt. These volcanoes often result in explosive eruptions. Along with lava, large quantities of pyroclastic material and ashes find their way to the ground. This material accumulates in the vicinity of the vent openings leading to formation of layers, and this makes the mounts appear as composite volcanoes. more than 50 m. Individual flows may extend for hundreds of km. The Deccan Traps from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province. It is believed that initially the trap formations covered a much larger area than the present. Mid-Ocean Ridge Volcanoes These volcanoes occur in the oceanic areas. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions. We shall be discussing this in detail in the next chapter. VOLCANIC LANDFORMS Intrusive Forms The lava that is released during volcanic eruptions on cooling develops into igneous rocks. The cooling may take place either on reaching the surface or also while the lava is still in the crustal portion. Depending on the location of the cooling of the lava, igneous rocks are classified as volcanic rocks (cooling at the surface) and plutonic rocks (cooling in the crust). The lava that cools within the crustal portions assumes different forms. These forms are called intrusive forms. Some of the forms are shown in Figure 3.4. Composite Volcano Caldera These are the most explosive of the earth's volcanoes. They are usually so explosive that when they erupt they tend to collapse on themselves rather than building any tall structure. The collapsed depressions are called calderas. Their explosiveness indicates that the magma chamber supplying the lava is not only huge but is also in close vicinity. Flood Basalt Provinces These volcanoes outpour highly fluid lava that flows for long distances. Some parts of the world are covered by thousands of sq. km of thick basalt lava flows. There can be a series of flows with some flows attaining thickness of Figure 3.4 : Volcanic Landforms Rationalised-2023-24 INTERIOR OF THE EARTH 25 Batholiths A large body of magmatic material that cools in the deeper depth of the crust develops in the form of large domes. They appear on the surface only after the denudational processes remove the overlying materials. They cover large areas, and at times, assume depth that may be several km. These are granitic bodies. Batholiths are the cooled portion of magma chambers. Lacoliths These are large dome-shaped intrusive bodies with a level base and connected by a pipe-like conduit from below. It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths. It can be regarded as the localised source of lava that finds its way to the surface. The Karnataka plateau is spotted with domal hills of granite rocks. Most of these, now exfoliated, are examples of lacoliths or batholiths. Lapolith, Phacolith and Sills As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane. It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called lapolith. A wavy mass of intrusive

rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country. Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the phacoliths. The near horizontal bodies of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material. The thinner ones are called sheets while the thick horizontal deposits are called sills. Dykes When the lava makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dykes. These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps. EXERCISES 1. Multiple choice questions. (i) Which one of the following earthquake waves is more destructive? (a) P-waves (c) Surface waves (b) S-waves (d) None of the above (ii) Which one of the following is a direct source of information about the interior of the earth? (a) Earthquake waves (c) Gravitational force (b) Volcanoes (d) Earth magnetism (iii) Which type of volcanic eruptions have caused Deccan Trap formations? (a) Shield (c) Composite (b) Flood (d) Caldera (iv) Which one of the following describes the lithosphere: (a) upper and lower mantle (c) crust and core (b) crust and upper mantle (d) mantle and core Rationalised-2023-24 26 FUNDAMENTALS OF PHYSICAL GEOGRAPHY 2. Answer the following questions in about 30 words. (i) What are body waves? (ii) Name the direct sources of information about the interior of the earth. (iii) Why do earthquake waves develop shadow zone? (iv) Briefly explain the indirect sources of information of the interior of the earth other than those of seismic activity. 3. Answer the following questions in about 150 words. (i) What are the effects of propagation of earthquake waves on the rock mass through which they travel? (ii) What do you understand by intrusive forms? Briefly describe various intrusive forms. Rationalised-2023-24In the previous chapter, you have studied the interior of the earth. You are already familiar with the world map. You know that continents cover 29 per cent of the surface of the earth and the remainder is under oceanic waters. The positions of the continents and the ocean bodies, as we see them in the map, have not been the same in the past. Moreover, it is now a well-accepted fact that oceans and continents will not continue to enjoy their present positions in times to come. If this is so, the question arises what were their positions in the past? Why and how do they change their positions? Even if it is true that the continents and oceans have changed and are changing their positions, you may wonder as to how scientists know this. How have they determined their earlier positions? You will find the answers to some of these and related questions in this chapter. CONTINENTAL DRIFT Observe the shape of the coastline of the Atlantic Ocean. You will be surprised by the symmetry of the coastlines on either side of the ocean. No wonder, many scientists thought of this similarity and considered the possibility of the two Americas, Europe and Africa, to be once joined together. From the known records of the history of science, it was Abraham Ortelius, a Dutch map maker, who first proposed such a possibility as early as 1596. Antonio Pellegrini drew a map showing the three continents together. However, it was Alfred Wegener—a German meteorologist who put forth a comprehensive argument in the form of “the continental drift DISTRIBUTION OF OCEANS AND CONTINENTS CHAPTER theory” in 1912. This was regarding the distribution of the oceans and the continents. According to Wegener, all the continents formed a single continental mass and mega ocean surrounded the same. The super continent was named PANGAEA, which meant all earth. The mega-ocean was called PANTHALASSA, meaning all water. He argued that, around 200 million years ago, the super continent, Pangaea, began to split. Pangaea first broke into two large continental masses as Laurasia and Gondwanaland forming the northern and southern components respectively. Subsequently, Laurasia and Gondwanaland continued to break into various smaller continents that exist today. A variety of evidence was offered in support of the continental drift. Some of these are given below. Evidence in Support of the Continental Drift The Matching of Continents (Jig-Saw-Fit) The shorelines of Africa and South America

facing each other have a remarkable and unmistakable match. It may be noted that a map produced using a computer programme to find the best fit of the Atlantic margin was presented by Bullard in 1964. It proved to be quite perfect. The match was tried at 1,000- fathom line instead of the present shoreline. Rocks of Same Age Across the Oceans The radiometric dating methods developed in the recent period have facilitated correlating the rock formation from different continents across Rationalised-2023-24 28 FUNDAMENTALS OF PHYSICAL GEOGRAPHY the vast ocean. The belt of ancient rocks of 2,000 million years from Brazil coast matches with those from western Africa. The earliest marine deposits along the coastline of South America and Africa are of the Jurassic age. This suggests that the ocean did not exist prior to that time. Tillite It is the sedimentary rock formed out of deposits of glaciers. The Gondawana system of sediments from India is known to have its counterparts in six different landmasses of the Southern Hemisphere. At the base, the system has thick tillite indicating extensive and prolonged glaciation. Counterparts of this succession are found in Africa, Falkland Island, Madagascar, Antarctica and Australia. Overall resemblance of the Gondawana-type sediments clearly demonstrates that these landmasses had remarkably similar histories. The glacial tillite provides unambiguous evidence of palaeoclimates and also of drifting of continents. Placer Deposits The occurrence of rich placer deposits of gold in the Ghana coast and the absolute absence of source rock in the region is an amazing fact. The gold bearing veins are in Brazil and it is obvious that the gold deposits of the Ghana are derived from the Brazil plateau when the two continents lay side by side. Distribution of Fossils When identical species of plants and animals adapted to living on land or in fresh water are found on either side of the marine barriers, a problem arises regarding accounting for such distribution. The observations that Lemurs occur in India, Madagascar and Africa led some to consider a contiguous landmass 'Lemuria' linking these three landmasses. Mesosaurus was a small reptile adapted to shallow brackish water. The skeletons of these are found only in two localities: the Southern Cape province of South Africa and Iraver formations of Brazil. The two localities are presently 4,800 km apart with an ocean in between them. Force for Drifting Wegener suggested that the movement responsible for the drifting of the continents was caused by pole-fleeing force and tidal force. The polar-fleeing force relates to the rotation of the earth. You are aware of the fact that the earth is not a perfect sphere; it has a bulge at the equator. This bulge is due to the rotation of the earth. The second force that was suggested by Wegener — the tidal force — is due to the attraction of the moon and the sun that develops tides in oceanic waters. Wegener believed that these forces would become effective when applied over many million years. However, most of scholars considered these forces to be totally inadequate. Post-drift Studies It is interesting to note that for continental drift, most of the evidence was collected from the continental areas in the form of distribution of flora and fauna or deposits, like tillite. A number of discoveries during the post–World War II period added new information to geological literature. Particularly, the information collected from the ocean floor mapping provided new dimensions for the study of distribution of oceans and continents. Convectional Current Theory Arthur Holmes in 1930s discussed the possibility of convection currents operating in the mantle portion. These currents are generated due to radioactive elements causing thermal differences in the mantle portion. Holmes argued that there exists a system of such currents in the entire mantle portion. This was an attempt to provide an explanation to the issue of force, on the basis of which contemporary scientists discarded the continental drift theory. Mapping of the Ocean Floor Detailed research of the ocean configuration revealed that the ocean floor is not just a vast plain but it is full of relief. Expeditions to map the oceanic floor in the post–World War II period provided a detailed picture of the ocean relief and indicated the existence of submerged Rationalised-2023-24 DISTRIBUTION OF OCEANS AND CONTINENTS 29 mountain ranges as well as deep trenches, mostly located closer to the continent margins. The mid-oceanic ridges were found to be most active in terms of volcanic eruptions. The dating of the rocks from the oceanic crust revealed the fact that

they are much younger than the continental areas. Rocks on either side of the crest of oceanic ridges and having equi-distant locations from the crest were found to have remarkable similarities both in terms of their constituents and their age. Ocean Floor Configuration In this section we shall note a few things related to the ocean floor configuration that help us in the understanding of the distribution of continents and oceans. You will be studying the details of ocean floor relief in Chapter 13. The ocean floor may be segmented into three major divisions based on the depth as well as the forms of relief. These divisions are continental margins, deep-sea basins and mid-ocean ridges. Abyssal Plains These are extensive plains that lie between the continental margins and mid-oceanic ridges. The abyssal plains are the areas where the continental sediments that move beyond the margins get deposited. Mid-Oceanic Ridges This forms an interconnected chain of mountain system within the ocean. It is the longest mountain-chain on the surface of the earth though submerged under the oceanic waters. It is characterised by a central rift system at the crest, a fractionated plateau and flank zone all along its length. The rift system at the crest is the zone of intense volcanic activity. In the previous chapter, you have been introduced to this type of volcanoes as midoceanic volcanoes. Distribution of Earthquakes and Volcanoes Study the maps showing the distribution of seismic activity and volcanoes given in Figure 4.2. You will notice a line of dots in the central parts of the Atlantic Ocean almost parallel to the coastlines. It further extends into the Indian Ocean. It bifurcates a little south of the Indian subcontinent with one branch moving into East Africa and the other meeting a similar line from Myanmar to New Guiana. You will notice that this line of dots coincides with the midoceanic ridges. The shaded belt showing another area of concentration coincides with the Alpine-Himalayan system and the rim of the Pacific Ocean. In general, the foci of the earthquake in the areas of mid-oceanic ridges are at shallow depths whereas along the Alpine-Himalayan belt as well as the rim of the Pacific, the earthquakes are deep-seated ones. The map of volcanoes also shows a similar pattern. The rim of the Pacific is also called rim of fire due to the existence of active volcanoes in this area. CONCEPT OF SEA FLOOR SPREADING As mentioned above, the post-drift studies provided considerable information that was not Figure 4.1 : Ocean Floor Continental Margins These form the transition between continental shores and deep-sea basins. They include continental shelf, continental slope, continental rise and deep-oceanic trenches. Of these, the deep-oceanic trenches are the areas which are of considerable interest in so far as the distribution of oceans and continents is concerned. Rationalised-2023-24 30 FUNDAMENTALS OF PHYSICAL GEOGRAPHY available at the time Wegener put forth his concept of continental drift. Particularly, the mapping of the ocean floor and palaeomagnetic studies of rocks from oceanic regions revealed the following facts : (i) It was realised that all along the midoceanic ridges, volcanic eruptions are common and they bring huge amounts of lava to the surface in this area. (ii) The rocks equidistant on either sides of the crest of mid-oceanic ridges show remarkable similarities in terms of period of formation, chemical compositions and magnetic properties. Rocks closer to the mid-oceanic ridges have normal polarity and are the youngest. The age of the rocks increases as one moves away from the crest. (iii) The ocean crust rocks are much younger than the continental rocks. The age of rocks in the oceanic crust is nowhere more than 200 million years old. Some of the continental rock formations are as old as 3,200 million years. (iv) The sediments on the ocean floor are unexpectedly very thin. Scientists were expecting, if the ocean floors were as old as the continent, to have a complete sequence of sediments for a period of much longer duration. However, nowhere was the sediment column found to be older than 200 million years. (v) The deep trenches have deep-seated earthquake occurrences while in the midoceanic ridge areas, the quake foci have shallow depths. These facts and a detailed analysis of magnetic properties of the rocks on either sides of the mid-oceanic ridge led Hess (1961) to propose his hypothesis, known as the “sea floor spreading”. Hess argued that constant eruptions at the crest of oceanic ridges cause the rupture of the oceanic crust and the new lava wedges into it, pushing the oceanic crust on either side. The

ocean floor, thus spreads. The younger age of the oceanic crust as well as the fact that the spreading of one ocean does not cause the shrinking of the other, made Hess Figure 4. 2 : Distribution of earthquakes and volcanoes Rationalised-2023-24 DISTRIBUTION OF OCEANS AND CONTINENTS 31 think about the consumption of the oceanic crust. He further maintained that the ocean floor that gets pushed due to volcanic eruptions at the crest, sinks down at the oceanic trenches and gets consumed. The basic concept of sea floor spreading has been depicted in Figure 4.3. PLATE TECTONICS Since the advent of the concept of sea floor spreading, the interest in the problem of distribution of oceans and continents was revived. It was in 1967, McKenzie and Parker and also Morgan, independently collected the available ideas and came out with another Figure 4. 3 : Sea floor spreading Figure 4.4 : Position of continents through geological past The motions of the continents during the past 540 million years. 1. Africa; 2. South America; 3. Antarctica; 4. Australia; 5. India; 6. China; 7. North America; 8. Europe; 9. and 10. Siberia (Emilani, 1992) Rationalised-2023-24 32 FUNDAMENTALS OF PHYSICAL GEOGRAPHY concept termed Plate Tectonics. A tectonic plate (also called lithospheric plate) is a massive, irregularly-shaped slab of solid rock, generally composed of both continental and oceanic lithosphere. Plates move horizontally over the asthenosphere as rigid units. The lithosphere includes the crust and top mantle with its thickness range varying between 5 and100 km in oceanic parts and about 200 km in the continental areas. A plate may be referred to as the continental plate or oceanic plate depending on which of the two occupy a larger portion of the plate. Pacific plate is largely an oceanic plate whereas the Eurasian plate may be called a continental plate. The theory of plate tectonics proposes that the earth's lithosphere is divided into seven major and some minor plates. Young Fold Mountain ridges, trenches, and/or faults surround these major plates (Figure 4.5). The major plates are as follows : Figure 4.5 : Major and minor plates of the world I Antarctica and the surrounding oceanic plate II North American (with western Atlantic floor separated from the South American plate along the Caribbean islands) plate III South American (with western Atlantic floor separated from the North American plate along the Caribbean islands) plate IV Pacific plate V India-Australia-New Zealand plate VI Africa with the eastern Atlantic floor plate VII Eurasia and the adjacent oceanic plate. Some important minor plates are listed below: (i) Cocos plate : Between Central America and Pacific plate (ii) Nazca plate : Between South America and Pacific plate (iii) Arabian plate : Mostly the Saudi Arabian landmass (iv) Philippine plate : Between the Asiatic and Pacific plate Rationalised-2023-24 DISTRIBUTION OF OCEANS AND CONTINENTS 33 (v) Caroline plate : Between the Philippine and Indian plate (North of New Guinea) (vi) Fuji plate : North-east of Australia. These plates have been constantly moving over the globe throughout the history of the earth. It is not the continent that moves as believed by Wegener. Continents are part of a plate and what moves is the plate. Moreover, it may be noted that all the plates, without exception, have moved in the geological past, and shall continue to move in the future as well. Wegener had thought of all the continents to have initially existed as a super continent in the form of Pangaea. However, later discoveries reveal that the continental masses, resting on the plates, have been wandering all through the geological period, and Pangaea was a result of converging of different continental masses that were parts of one or the other plates. Scientists using the palaeomagnetic data have determined the positions held by each of the present continental landmass in different geological periods (Fig 4.4). Position of the Indian subcontinent (mostly Peninsular India) is traced with the help of the rocks analysed from the Nagpur area. There are three types of plate boundaries: Divergent Boundaries Where new crust is generated as the plates pull away from each other. The sites where the plates move away from each other are called spreading sites. The best-known example of divergent boundaries is the Mid-Atlantic Ridge. At this, the American Plate(s) is/are separated from the Eurasian and African Plates. Convergent Boundaries Where the crust is destroyed as one plate dived under another. The location where sinking of a plate occurs is called a subduction zone. There are three ways in which convergence can occur. These are: (i) between an oceanic and continental

plate; (ii) between two oceanic plates; and (iii) between two continental plates. Transform Boundaries Where the crust is neither produced nor destroyed as the plates slide horizontally past each other. Transform faults are the planes of separation generally perpendicular to the midoceanic ridges. As the eruptions do not take all along the entire crest at the same time, there is a differential movement of a portion of the plate away from the axis of the earth. Also, the rotation of the earth has its effect on the separated blocks of the plate portions. How do you think the rate of plate movement is determined? Rates of Plate Movement The strips of normal and reverse magnetic field that parallel the mid-oceanic ridges help scientists determine the rates of plate movement. These rates vary considerably. The Arctic Ridge has the slowest rate (less than 2.5 cm/yr), and the East Pacific Rise near Easter Island, in the South Pacific about 3,400 km west of Chile, has the fastest rate (more than 15 cm/yr). Force for the Plate Movement At the time that Wegener proposed his theory of continental drift, most scientists believed that the earth was a solid, motionless body. However, concepts of sea floor spreading and the unified theory of plate tectonics have emphasised that both the surface of the earth and the interior are not static and motionless but are dynamic. The fact that the plates move is now a well-accepted fact. The mobile rock beneath the rigid plates is believed to be moving in a circular manner. The heated material rises to the surface, spreads and begins to cool, and then sinks back into deeper depths. This cycle is repeated over and over to generate what scientists call a convection cell or convective flow. Heat within the earth comes from two main sources: radioactive decay and residual heat. Arthur Holmes first considered Rationalised-2023-24 34 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Figure 4.6 : Movement of the Indian plate this idea in the 1930s, which later influenced Harry Hess' thinking about seafloor spreading. The slow movement of hot, softened mantle that lies below the rigid plates is the driving force behind the plate movement. MOVEMENT OF THE INDIAN PLATE The Indian plate includes Peninsular India and the Australian continental portions. The subduction zone along the Himalayas forms the northern plate boundary in the form of continent— continent convergence. In the east, it extends through Rakinyoma Mountains of Myanmar towards the island arc along the Java Trench. The eastern margin is a spreading site lying to the east of Australia in the form of an oceanic ridge in SW Pacific. The Western margin follows Kirthar Mountain of Pakistan. It further extends along the Makrana coast and joins the spreading site from the Red Sea rift southeastward along the Chagos Archipelago. The boundary between India and the Antarctic plate is also marked by oceanic ridge (divergent boundary) running in roughly W-E direction and merging into the spreading site, a little south of New Zealand. India was a large island situated off the Australian coast, in a vast ocean. The Tethys Sea separated it from the Asian continent till about 225 million years ago. India is supposed to have started her northward journey about 200 million years ago at the time when Pangaea broke. India collided with Asia about 40-50 million years ago causing rapid uplift of the Himalayas. The positions of India since about 71 million years till the present are shown in the Figure 4.6. It also shows the position of the Indian subcontinent and the Eurasian plate. About 140 million years before the present, the subcontinent was located as south as 50oS. latitude. The two major plates were separated by the Tethys Sea and the Tibetan block was closer to the Asiatic landmass. During the movement of the Indian plate towards the Eurasian plate, a major event that occurred was the outpouring of lava and formation of the Deccan Traps. This started somewhere around 60 million years ago and continued for a long period of time. Note that the subcontinent was still close to the equator. From 40 million years ago and thereafter, the event of formation of the Himalayas took place. Scientists believe that the process is still continuing and the height of the Himalayas is rising even to this date. Rationalised-2023-24 DISTRIBUTION OF OCEANS AND CONTINENTS 35 EXERCISES 1. Multiple choice questions. (i) Who amongst the following was the first to consider the possibility of Europe, Africa and America having been located side by side. (a) Alfred Wegener (c) Abraham Ortelius (b) Antonio Pellegrini (d) Edmond Hess (ii) Polar fleeing force relates to: (a) Revolution of the Earth (c) Rotation of the earth (b)

Gravitation (d) Tides (iii) Which one of the following is not a minor plate? (a) Nazca (c) Philippines (b) Arabia (d) Antarctica (iv) Which one of the following facts was not considered by those while discussing the concept of sea floor spreading? (a) Volcanic activity along the mid-oceanic ridges. (b) Stripes of normal and reverse magnetic field observed in rocks of ocean floor. (c) Distribution of fossils in different continents. (d) Age of rocks from the ocean floor. (v) Which one of the following is the type of plate boundary of the Indian plate along the Himalayan mountains? (a) Ocean-continent convergence (b) Divergent boundary (c) Transform boundary (d) Continent-continent convergence 2. Answer the following questions in about 30 words. (i) What were the forces suggested by Wegener for the movement of the continents? (ii) How are the convectional currents in the mantle initiated and maintained? (iii) What is the major difference between the transform boundary and the convergent or divergent boundaries of plates? (iv) What was the location of the Indian landmass during the formation of the Deccan Traps? 3. Answer the following questions in about 150 words. (i) What are the evidences in support of the continental drift theory? (ii) Bring about the basic difference between the drift theory and Plate tectonics. (iii) What were the major post-drift discoveries that rejuvenated the interest of scientists in the study of distribution of oceans and continents? Project Work Prepare a collage related to damages caused by an earthquake. Rationalised-2023-24LANDFORMS This unit deals with • Landforms and their evolution • Geomorphic processes — weathering, mass wasting, erosion and deposition; soils — formation UNIT III Rationalised-2023-24 GEOMORPHIC PROCESSES CHAPTER A fter learning about how the earth was born, how it evolved its crust and other inner layers, how its crustal plates moved and are moving, and other information on earthquakes, the forms of volcanism and about the rocks and minerals the crust is composed of, it is time to know in detail about the surface of the earth on which we live. Let us start with this question. Why is the surface of the earth uneven? The earth's crust is dynamic. You are well aware that it has moved and moves vertically and horizontally. Of course, it moved a bit faster in the past than the rate at which it is moving now. The differences in the internal forces operating from within the earth which built up the crust have been responsible for the variations in the outer surface of the crust. The earth's surface is being continuously subjected to external forces induced basically by energy (sunlight). Of course, the internal forces are still active though with different intensities. That means, the earth's surface is being continuously subjected to by external forces originating within the earth's atmosphere and by internal forces from within the earth. The external forces are known as exogenic forces and the internal forces are known as endogenic forces. The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up (aggradation) of basins/ depressions, on the earth's surface. The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as gradation. The endogenic forces continuously elevate or build up parts of the earth's surface and hence the exogenic processes fail to even out the relief variations of the surface of the earth. So, variations remain as long as the opposing actions of exogenic and endogenic forces continue. In general terms, the endogenic forces are mainly land building forces and the exogenic processes are mainly land wearing forces. The surface of the earth is sensitive. Humans depend on it for their sustenance and have been using it extensively and intensively. So, it is essential to understand its nature in order to use it effectively without disturbing its balance and diminishing its potential for the future. Almost all organisms contribute to sustain the earth's environment. However, humans have caused extensive damage to the environment through over use of resources. Use we must, but must also leave it potential enough to sustain life through the future. Most of the surface of the earth had and has been shaped over very long periods of time (hundreds and thousands of years) and because of its use and misuse by humans its potential is being diminished at a fast rate. If the processes which shaped and are shaping the surface of the earth into varieties of forms (shapes) and the nature of materials of which it is composed of, are understood, precautions can be taken to minimise the detrimental effects of

human use and to preserve it for posterity. GEOMORPHIC PROCESSES You would like to know the meaning of geomorphic processes. The endogenic and exogenic forces causing physical stresses and chemical actions on earth materials and Rationalised-2023-24 38 FUNDAMENTALS OF PHYSICAL GEOGRAPHY bringing about changes in the configuration of the surface of the earth are known as geomorphic processes. Diastrophism and volcanism are endogenic geomorphic processes. These have already been discussed in brief in the preceding unit. Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes. These exogenic processes are dealt with in detail in this chapter. Any exogenic element of nature (like water, ice, wind, etc.,) capable of acquiring and transporting earth materials can be called a geomorphic agent. When these elements of nature become mobile due to gradients, they remove the materials and transport them over slopes and deposit them at lower level. Geomorphic processes and geomorphic agents especially exogenic, unless stated separately, are one and the same. A process is a force applied on earth materials affecting the same. An agent is a mobile medium (like running water, moving ice masses, wind, waves and currents etc.) which removes, transports and deposits earth materials. Running water, groundwater, glaciers, wind, waves and currents, etc., can be called geomorphic agents. Do you think it is essential to distinguish geomorphic agents and geomorphic processes? Gravity besides being a directional force activating all downslope movements of matter also causes stresses on the earth's materials. Indirect gravitational stresses activate wave and tide induced currents and winds. Without gravity and gradients there would be no mobility and hence no erosion, transportation and deposition are possible. So, gravitational stresses are as important as the other geomorphic processes. Gravity is the force that is keeping us in contact with the surface and it is the force that switches on the movement of all surface material on earth. All the movements either within the earth or on the surface of the earth occur due to gradients — from higher levels to lower levels, from high pressure to low pressure areas etc. ENDOGENIC PROCESSES The energy emanating from within the earth is the main force behind endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth. This energy due to geothermal gradients and heat flow from within induces diastrophism and volcanism in the lithosphere. Due to variations in geothermal gradients and heat flow from within, crustal thickness and strength, the action of endogenic forces are not uniform and hence the tectonically controlled original crustal surface is uneven. Diastrophism All processes that move, elevate or build up portions of the earth's crust come under diastrophism. They include: (i) orogenic processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust; (ii) epeirogenic processes involving uplift or warping of large parts of the earth's crust; (iii) earthquakes involving local relatively minor movements; (iv) plate tectonics involving horizontal movements of crustal plates. In the process of orogeny, the crust is severely deformed into folds. Due to epeirogeny, there may be simple deformation. Orogeny is a mountain building process whereas epeirogeny is continental building process. Through the processes of orogeny, epeirogeny, earthquakes and plate tectonics, there can be faulting and fracturing of the crust. All these processes cause pressure, volume and temperature (PVT) changes which in turn induce metamorphism of rocks. Epeirogeny and orogeny, cite the differences. Volcanism Volcanism includes the movement of molten rock (magma) onto or toward the earth's surface and also formation of many intrusive and extrusive volcanic forms. Many aspects of volcanism have already been dealt in detail Rationalised-2023-24 GEOMORPHIC PROCESSES 39 driving forces. It should become clear from this chart that for each process there exists a distinct driving force or energy. As there are different climatic regions owing to variations in thermal gradients created by latitudinal, seasonal, and land and water spread on the surface of the earth, the exogenic geomorphic processes vary from region to region. The density, type and distribution of vegetation which largely depend upon precipitation and temperature also exert under volcanoes in the Unit II and under igneous rocks in the preceding

chapter in this unit. What do the words volcanism and volcanoes indicate? EXOGENIC PROCESSES The exogenic processes derive their energy from atmosphere determined by the ultimate energy from the sun and also the gradients created by tectonic factors. Why do you think that the slopes or gradients are created by tectonic factors? Gravitational force acts upon all earth materials having a sloping surface and tend to produce movement of matter in down slope direction. Force applied per unit area is called stress. Stress is produced in a solid by pushing or pulling. This induces deformation. Forces acting along the faces of earth materials are shear stresses (separating forces). It is this stress that breaks rocks and other earth materials. The shear stresses result in angular displacement or slippage. Besides the gravitational stress earth materials become subjected to molecular stresses that may be caused by a number of factors amongst which temperature changes, crystallisation and melting are the most common. Chemical processes normally lead to loosening of bonds between grains, dissolving of soluble minerals or cementing materials. Thus, the basic reason that leads to weathering, mass movements, and erosion is development of stresses in the body of the earth materials. Temperature and precipitation are the two important climatic elements that control various processes. All the exogenic geomorphic processes are covered under a general term, denudation. The word 'denude' means to strip off or to uncover. Weathering, mass wasting/movements, erosion and transportation are included in denudation. The flow chart (Figure 5.1) gives the denudation processes and their respective influence indirectly on exogenic geomorphic processes. Within different climatic regions there may be local variations of the effects of different climatic elements due to altitudinal differences, aspect variations and the variation in the amount of insolation received by north and south facing slopes as compared to east and west facing slopes. Further, due to differences in wind velocities and directions, amount and kind of precipitation, its intensity, the relation between precipitation and evaporation, daily range of temperature, freezing and thawing frequency, depth of frost penetration, the geomorphic processes vary within any climatic region. What is the sole driving force behind all the exogenic processes? Climatic factors being equal, the intensity of action of exogenic geomorphic processes depends upon type and structure of rocks. The term structure includes such aspects of rocks as folds, faults, orientation and inclination of beds, presence or absence of joints, bedding planes, hardness or softness of constituent minerals, chemical susceptibility of mineral constituents; the permeability or impermeability Figure 5.1 : Denudational processes and their driving forces Rationalised-2023-24 40 FUNDAMENTALS OF PHYSICAL GEOGRAPHY etc. Different types of rocks with differences in their structure offer varying resistances to various geomorphic processes. A particular rock may be resistant to one process and nonresistant to another. And, under varying climatic conditions, particular rocks may exhibit different degrees of resistance to geomorphic processes and hence they operate at differential rates and give rise to differences in topography. The effects of most of the exogenic geomorphic processes are small and slow and may be imperceptible in a short time span, but will in the long run affect the rocks severely due to continued fatigue. Finally, it boils down to one fact that the differences on the surface of the earth though originally related to the crustal evolution continue to exist in some form or the other due to differences in the type and structure of earth materials, differences in geomorphic processes and in their rates of operation. Some of the exogenic geomorphic processes have been dealt in detail here. WEATHERING Weathering is action of elements of weather and climate over earth materials. There are a number of processes within weathering which act either individually or together to affect the earth materials in order to reduce them to fragmental state. Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate. As very little or no motion of materials takes place in weathering, it is an in-situ or on-site process. Is this little motion which can occur sometimes due to weathering synonymous with transportation? If not, why? Weathering processes are conditioned by many complex geological, climatic, topographic and vegetative factors.

Climate is of particular importance. Not only weathering processes differ from climate to climate, but also the depth of the weathering mantle (Figure 5.2). Figure 5.2 : Climatic regimes and depth of weathering mantles (adapted and modified from Strakhov, 1967) Activity Mark the latitude values of different climatic regimes in Figure 6.2 and compare the details. There are three major groups of weathering processes : (i) chemical; (ii) physical or mechanical; (iii) biological weathering processes. Very rarely does any one of these processes ever operate completely by itself, but quite often a dominance of one process can be seen. Chemical Weathering Processes A group of weathering processes viz; solution, carbonation, hydration, oxidation and reduction act on the rocks to decompose, dissolve or reduce them to a fine clastic state through chemical reactions by oxygen, surface and/or soil water and other acids. Water and air (oxygen and carbon dioxide) along with heat must be present to speed up all chemical reactions. Over and above the carbon dioxide present in the air, decomposition of plants and animals increases the quantity of carbon dioxide underground. These chemical reactions on various minerals are very much similar to the chemical reactions in a laboratory. Physical Weathering Processes Physical or mechanical weathering processes depend on some applied forces. The applied Rationalised-2023-24 GEOMORPHIC PROCESSES 41 forces could be: (i) gravitational forces such as overburden pressure, load and shearing stress; (ii) expansion forces due to temperature changes, crystal growth or animal activity; (iii) water pressures controlled by wetting and drying cycles. Many of these forces are applied both at the surface and within different earth materials leading to rock fracture. Most of the physical weathering processes are caused by thermal expansion and pressure release. These processes are small and slow but can cause great damage to the rocks because of continued fatigue the rocks suffer due to repetition of contraction and expansion. BIOLOGICAL ACTIVITY AND WEATHERING Biological weathering is contribution to or removal of minerals and ions from the weathering environment and physical changes due to growth or movement of organisms. Burrowing and wedging by organisms like earthworms, termites, rodents etc., help in exposing the new surfaces to chemical attack and assists in the penetration of moisture and air. Human beings by disturbing vegetation, ploughing and cultivating soils, also help in mixing and creating new contacts between air, water and minerals in the earth materials. Decaying plant and animal matter help in the production of humic, carbonic and other acids which enhance decay and solubility of some elements. Plant roots exert a tremendous pressure on the earth materials mechanically breaking them apart. SPECIAL EFFECTS OF WEATHERING Exfoliation This has already been explained under physical weathering processes of unloading, thermal contraction and expansion and salt weathering. Exfoliation is a result but not a process. Flaking off of more or less curved sheets of shells from over rocks or bedrock results in smooth and rounded surfaces (Figure 5.3). Exfoliation can occur due to expansion and contraction induced by temperature changes. Exfoliation domes and tors result due to unloading and thermal expansion respectively. SIGNIFICANCE OF WEATHERING Weathering processes are responsible for breaking down the rocks into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements. Biomes and bio-diversity is basically a result of forests (vegetation) and forests depend upon the depth of weathering mantles. Erosion cannot be significant if the rocks are not weathered. That means, weathering aids mass wasting, erosion and reduction of relief and changes in landforms are a consequence of erosion. Weathering of rocks and deposits helps in the enrichment and concentrations of certain valuable ores of iron, manganese, aluminium, copper etc., which are of great importance for the national economy. Weathering is an important process in the formation of soils. When rocks undergo weathering, some materials are removed through chemical or physical leaching by groundwater and thereby the concentration of remaining (valuable) materials increases. Without such a weathering taking place, the concentration of the same valuable material may not be sufficient and economically viable to exploit, process and refine. This is what is called enrichment. MASS MOVEMENTS These movements transfer the mass of rock debris down the slopes

under the direct influence of gravity. That means, air, water or Fig.5.3 : Exfoliation (Flacking) and granular disintegration Rationalised-2023-24 42 FUNDAMENTALS OF PHYSICAL GEOGRAPHY ice do not carry debris with them from place to place but on the other hand the debris may carry with it air, water or ice. The movements of mass may range from slow to rapid, affecting shallow to deep columns of materials and include creep, flow, slide and fall. Gravity exerts its force on all matter, both bedrock and the products of weathering. So, weathering is not a pre-requisite for mass movement though it aids mass movements. Mass movements are very active over weathered slopes rather than over unweathered materials. Mass movements are aided by gravity and no geomorphic agent like running water, glaciers, wind, waves and currents participate in the process of mass movements. That means mass movements do not come under erosion though there is a shift (aided by gravity) of materials from one place to another. Materials over the slopes have their own resistance to disturbing forces and will yield only when force is greater than the shearing resistance of the materials. Weak unconsolidated materials, thinly bedded rocks, faults, steeply dipping beds, vertical cliffs or steep slopes, abundant precipitation and torrential rains and scarcity of vegetation etc., favour mass movements. Several activating causes precede mass movements. They are : (i) removal of support from below to materials above through natural or artificial means; (ii) increase in gradient and height of slopes; (iii) overloading through addition of materials naturally or by artificial filling; (iv) overloading due to heavy rainfall, saturation and lubrication of slope materials; (v) removal of material or load from over the original slope surfaces; (vi) occurrence of earthquakes, explosions or machinery; (vii) excessive natural seepage; (viii) heavy drawdown of water from lakes, reservoirs and rivers leading to slow outflow of water from under the slopes or river banks; (ix) indiscriminate removal of natural vegetation. Heave (heaving up of soils due to frost growth and other causes), flow and slide are the three forms of movements. Figure 5.5 shows the relationships among different types of mass movements, their relative rates of movement and moisture limits. Landslides These are relatively rapid and perceptible movements. The materials involved are relatively dry. The size and shape of the detached mass depends on the nature of discontinuities in the rock, the degree of weathering and the steepness of the slope. Depending upon the type of movement of materials several types are identified in this category. Slump is slipping of one or several units of rock debris with a backward rotation with respect to the slope over which the movement takes place (Figure 5.4). Rapid rolling or sliding Figure 5.5 : Landslide scars in Shiwalik Himalayan ranges near river Sarada at India-Nepal border, Uttar Pradesh of earth debris without backward rotation of mass is known as debris slide. Debris fall is nearly a free fall of earth debris from a vertical or overhanging face. Sliding of individual rock masses down bedding, joint or fault surfaces is rockslide. Over steep slopes, rock sliding is very fast and destructive. Figure 5.5 shows landslide scars over steep slopes. Slides occur as planar failures along discontinuities like Figure 5.4 : Slumping of debris with backward rotation Rationalised-2023-24 GEOMORPHIC PROCESSES 43 bedding planes that dip steeply. Rock fall is free falling of rock blocks over any steep slope keeping itself away from the slope. Rock falls occur from the superficial layers of the rock face, an occurrence that distinguishes it from rockslide which affects materials up to a substantial depth. Between mass wasting and mass movements, which term do you feel is most appropriate? Why? Can solifluction be included under rapid flow movements? Why it can be and can’t be? In our country, debris avalanches and landslides occur very frequently in the Himalayas. There are many reasons for this. One, the Himalayas are tectonically active. They are mostly made up of sedimentary rocks and unconsolidated and semi-consolidated deposits. The slopes are very steep. Compared to the Himalayas, the Nilgiris bordering Tamilnadu, Karnataka, Kerala and the Western Ghats along the west coast are relatively tectonically stable and are mostly made up of very hard rocks; but, still, debris avalanches and landslides occur though not as frequently as in the Himalayas, in these hills. Why? Many slopes are steeper with almost vertical cliffs and escarpments in the Western Ghats and Nilgiris. Mechanical weathering due to temperature

changes and ranges is pronounced. They receive heavy amounts of rainfall over short periods. So, there is almost direct rock fall quite frequently in these places along with landslides and debris avalanches. EROSION AND DEPOSITION Erosion involves acquisition and transportation of rock debris. When massive rocks break into smaller fragments through weathering and any other process, erosional geomorphic agents like running water, groundwater, glaciers, wind and waves remove and transport it to other places depending upon the dynamics of each of these agents. Abrasion by rock debris carried by these geomorphic agents also aids greatly in erosion. By erosion, relief degrades, i.e., the landscape is worn down. That means, though weathering aids erosion it is not a pre-condition for erosion to take place. Weathering, mass-wasting and erosion are degradational processes. It is erosion that is largely responsible for continuous changes that the earth's surface is undergoing. As indicated in Figure 6.1, denudational processes like erosion and transportation are controlled by kinetic energy. The erosion and transportation of earth materials is brought about by wind, running water, glaciers, waves and ground water. Of these the first three agents are controlled by climatic conditions. They represent three states of matter —gaseous (wind), liquid (running water) and solid (glacier) respectively. Can you compare the three climatically controlled agents? The work of the other two agents of erosion-waves and ground water is not controlled by climate. In case of waves it is the location along the interface of litho and hydro sphere — coastal region — that will determine the work of waves, whereas the work of ground water is determined more by the lithological character of the region. If the rocks are permeable and soluble and water is available only then karst topography develops. In the next chapter we shall be dealing with the landforms produced by each of these agents of erosion. Deposition is a consequence of erosion. The erosional agents loose their velocity and hence energy on gentler slopes and the materials carried by them start to settle themselves. In other words, deposition is not actually the work of any agent. The coarser materials get deposited first and finer ones later. By deposition depressions get filled up. The same erosional agents viz., running water, glaciers, wind, waves and groundwater act as aggradational or depositional agents also. What happens to the surface of the earth due to erosion and deposition is elaborated Rationalised-2023-24 44 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Is weathering solely responsible for soil formation? If not, why? Pedology is soil science. A pedologist is a soil-scientist. Soil-forming Factors Five basic factors control the formation of soils: (i) parent material; (ii) topography; (iii) climate; (iv) biological activity; (v) time. In fact soil forming factors act in union and affect the action of one another. Parent Material Parent material is a passive control factor in soil formation. Parent materials can be any in-situ or on-site weathered rock debris (residual soils) or transported deposits (transported soils). Soil formation depends upon the texture (sizes of debris) and structure (disposition of individual grains/particles of debris) as well as the mineral and chemical composition of the rock debris/deposits. Nature and rate of weathering and depth of weathering mantle are important considerations under parent materials. There may be differences in soil over similar bedrock and dissimilar bedrocks may have similar soils above them. But when soils are very young and have not matured these show strong links with the type of parent rock. Also, in case of some limestone areas, where the weathering processes are specific and peculiar, soils will show clear relation with the parent rock. Topography Topography like parent materials is another passive control factor. The influence of topography is felt through the amount of exposure of a surface covered by parent materials to sunlight and the amount of surface and sub-surface drainage over and through the parent materials. Soils will be thin on steep slopes and thick over flat upland areas. Over gentle slopes where erosion is slow and percolation of water is good, soil formation is in the next chapter on landforms and their evolution. There is a shift of materials in mass movements as well as in erosion from one place to the other. So, why can't both be treated as one and the same? Can there be appreciable erosion without rocks undergoing weathering? SOIL FORMATION You see plants growing in soils. You play in the ground and come into contact with soil. You touch and feel soil and

soil your clothes while playing. Can you describe it? Soil is a dynamic medium in which many chemical, physical and biological activities go on constantly. Soil is a result of decay, it is also the medium for growth. It is a changing and developing body. It has many characteristics that fluctuate with the seasons. It may be alternatively cold and warm or dry and moist. Biological activity is slowed or stopped if the soil becomes too cold or too dry. Organic matter increases when leaves fall or grasses die. Process of Soil Formation Soil formation or pedogenesis depends first on weathering. It is this weathering mantle (depth of the weathered material) which is the basic input for soil to form. First, the weathered material or transported deposits are colonised by bacteria and other inferior plant bodies like mosses and lichens. Also, several minor organisms may take shelter within the mantle and deposits. The dead remains of organisms and plants help in humus accumulation. Minor grasses and ferns may grow; later, bushes and trees will start growing through seeds brought in by birds and wind. Plant roots penetrate down, burrowing animals bring up particles, mass of material becomes porous and sponge-like with a capacity to retain water and to permit the passage of air and finally a mature soil, a complex mixture of mineral and organic products forms. Rationalised-2023-24 GEOMORPHIC PROCESSES 45 very favourable. Soils over flat areas may develop a thick layer of clay with good accumulation of organic matter giving the soil dark colour. Climate Climate is an important active factor in soil formation. The climatic elements involved in soil development are : (i) moisture in terms of its intensity, frequency and duration of precipitation - evaporation and humidity; (ii) temperature in terms of seasonal and diurnal variations. Precipitation gives soil its moisture content which makes the chemical and biological activities possible. Excess of water helps in the downward transportation of soil components through the soil (eluviation) and deposits the same down below (illuviation). In climates like wet equatorial rainy areas with high rainfall, not only calcium, sodium, magnesium, potassium etc. but also a major part of silica is removed from the soil. Removal of silica from the soil is known as desilication. In dry climates, because of high temperature, evaporation exceeds precipitation and hence ground water is brought up to the surface by capillary action and in the process the water evaporates leaving behind salts in the soil. Such salts form into a crust in the soil known as hardpans. In tropical climates and in areas with intermediate precipitation conditions, calcium carbonate nodules (kanker) are formed. Temperature acts in two ways — increasing or reducing chemical and biological activity. Chemical activity is increased in higher temperatures, reduced in cooler temperatures (with an exception of carbonation) and stops in freezing conditions. That is why, tropical soils with higher temperatures show deeper profiles and in the frozen tundra regions soils contain largely mechanically broken materials. Biological Activity The vegetative cover and organisms that occupy the parent materials from the beginning and also at later stages help in adding organic matter, moisture retention, nitrogen etc. Dead plants provide humus, the finely divided organic matter of the soil. Some organic acids which form during humification aid in decomposing the minerals of the soil parent materials. Intensity of bacterial activity shows up differences between soils of cold and warm climates. Humus accumulates in cold climates as bacterial growth is slow. With undecomposed organic matter because of low bacterial activity, layers of peat develop in subarctic and tundra climates. In humid tropical and equatorial climates, bacterial growth and action is intense and dead vegetation is rapidly oxidised leaving very low humus content in the soil. Further, bacteria and other soil organisms take gaseous nitrogen from the air and convert it into a chemical form that can be used by plants. This process is known as nitrogen fixation. Rhizobium, a type of bacteria, lives in the root nodules of leguminous plants and fixes nitrogen beneficial to the host plant. The influence of large animals like ants, termites, earthworms, rodents etc., is mechanical, but, it is nevertheless important in soil formation as they rework the soil up and down. In case of earthworms, as they feed on soil, the texture and chemistry of the soil that comes out of their body changes. Time Time is the third important controlling factor in soil formation. The length of time the soil forming processes operate, determines maturation of soils and profile

development. A soil becomes mature when all soil-forming processes act for a sufficiently long time developing a profile. Soils developing from recently deposited alluvium or glacial till are considered young and they exhibit no horizons or only poorly developed horizons. No specific length of time in absolute terms can be fixed for soils to develop and mature. Is it necessary to separate the process of soil formation and the soil forming control factors? Why are time, topography and parent material considered as passive control factors in soil formation? Rationalised-2023-24 46 FUNDAMENTALS OF PHYSICAL GEOGRAPHY EXERCISES 1. Multiple choice questions. (i) Which one of the following processes is a gradational process? (a) Deposition (c) Volcanism (b) Diastrophism (d) Erosion (ii) Which one of the following materials is affected by hydration process? (a) Granite (c) Quartz (b) Clay (d) Salts (iii) Debris avalanche can be included in the category of: (a) Landslides (c) Rapid flow mass movements (b) Slow flow mass movements (d) Subsidence 2. Answer the following questions in about 30 words. (i) It is weathering that is responsible for bio-diversity on the earth. How? (ii) What are mass movements that are real rapid and perceptible? List. (iii) What are the various mobile and mighty exogenic geomorphic agents and what is the prime job they perform? (iv) Is weathering essential as a pre-requisite in the formation of soils? Why? 3. Answer the following questions in about 150 words. (i) “Our earth is a playfield for two opposing groups of geomorphic processes.” Discuss. (ii) Exogenic geomorphic processes derive their ultimate energy from the sun’s heat. Explain. (iii) Are physical and chemical weathering processes independent of each other? If not, why? Explain with examples. (iv) How do you distinguish between the process of soil formation and soilforming factors? What is the role of climate and biological activity as two important control factors in the formation of soils? Project Work Depending upon the topography and materials around you, observe and record climate, possible weathering process and soil contents and characteristics. Rationalised-2023-24LANDFORMS AND THEIR EVOLUTION A fter weathering processes have had their actions on the earth materials making up the surface of the earth, the geomorphic agents like running water, ground water, wind, glaciers, waves perform erosion. It is already known to you that erosion causes changes on the surface of the earth. Deposition follows erosion and because of deposition too, changes occur on the surface of the earth. As this chapter deals with landforms and their evolution ‘first’ start with the question, what is a landform? In simple words, small to medium tracts or parcels of the earth’s surface are called landforms. If landform is a small to medium sized part of the surface of the earth, what is a landscape? Several related landforms together make up landscapes, (large tracts of earth’s surface). Each landform has its own physical shape, size, materials and is a result of the action of certain geomorphic processes and agent(s). Actions of most of the geomorphic processes and agents are slow, and hence the results take a long time to take shape. Every landform has a beginning. Landforms once formed may change in their shape, size and nature slowly or fast due to continued action of geomorphic processes and agents. Due to changes in climatic conditions and vertical or horizontal movements of landmasses, either the intensity of processes or the processes themselves might change leading to new modifications in the landforms. Evolution here implies stages of transformation of either a part of the earth’s surface from one landform into another or transformation of individual landforms after they are once formed. That means, each and every landform has a history of development and changes through time. A landmass passes through stages of development somewhat comparable to the stages of life — youth, mature and old age. What are the two important aspects of the evolution of landforms? RUNNING WATER In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land surface. There are two components of running water. One is overland flow on general land surface as a sheet. Another is linear flow as streams and rivers in valleys. Most of the erosional landforms made by running water are associated with vigorous and youthful rivers flowing over steep gradients. With time, stream channels over steep gradients turn gentler due to continued erosion, and as a consequence, lose their velocity,

facilitating active deposition. There may be depositional forms associated with streams flowing over steep slopes. But these phenomena will be on a small scale compared to those associated with rivers flowing over medium to gentle slopes. The gentler the river channels in gradient or slope, the greater is the deposition. When the stream beds turn gentler due to continued erosion, downward CHAPTER Rationalised-2023-24 48 FUNDAMENTALS OF PHYSICAL GEOGRAPHY cutting becomes less dominant and lateral erosion of banks increases and as a consequence the hills and valleys are reduced to plains. Is complete reduction of relief of a high land mass possible? Overland flow causes sheet erosion. Depending upon irregularities of the land surface, the overland flow may concentrate into narrow to wide paths. Because of the sheer friction of the column of flowing water, minor or major quantities of materials from the surface of the land are removed in the direction of flow and gradually small and narrow rills will form. These rills will gradually develop into long and wide gullies; the gullies will further deepen, widen, lengthen and unite to give rise to a network of valleys. In the early stages, down-cutting dominates during which irregularities such as waterfalls and cascades will be removed. In the middle stages, streams cut their beds slower, and lateral erosion of valley sides becomes severe. Gradually, the valley sides are reduced to lower and lower slopes. The divides between drainage basins are likewise lowered until they are almost completely flattened leaving finally, a lowland of faint relief with some low resistant remnants called monadnocks standing out here and there. This type of plain forming as a result of stream erosion is called a peneplain (an almost plain). The characteristics of each of the stages of landscapes developing in running water regimes may be summarised as follows: Youth Streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no floodplains or with very narrow floodplains along trunk streams. Streams divides are broad and flat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exist where local hard rock bodies are exposed. Mature During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley. The flat and broad inter stream areas and swamps and marshes of youth disappear and the stream divides turn sharp. Waterfalls and rapids disappear. Old Smaller tributaries during old age are few with gentle gradients. Streams meander freely over vast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level. EROSIONAL LANDFORMS Valleys Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys. Depending upon dimensions and shape, many types of valleys like V-shaped valley, gorge, canyon, etc. can be recognised. A gorge is a deep valley with very steep to straight sides (Figure 6.1) and a canyon is characterised by steep step-like side slopes (Figure 6.2) and may be as deep as a gorge. A gorge is almost equal in width at its top as well as its bottom. In contrast, a canyon is wider at its top than at its bottom. In fact, a canyon is a variant of gorge. Valley types depend upon the type and structure of rocks in which they form. For example, canyons commonly form in horizontal bedded sedimentary rocks and gorges form in hard rocks. Potholes and Plunge Pools Over the rocky beds of hill-streams more or less circular depressions called potholes form because of stream erosion aided by the abrasion of rock fragments. Once a small and Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 49 shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water and consequently the depressions grow in dimensions. A series of such depressions eventually join and the stream valley gets deepened. At the foot of Figure 6.1 : The Valley of Kaveri river near Hogenekal, Dharmapuri district, Tamil Nadu in the form of gorge Figure 6.2 : An entrenched meander loop of river Colorado in USA showing step-like side slopes of its valley typical of a canyon waterfalls also, large potholes, quite deep and wide, form because of

the sheer impact of water and rotation of boulders. Such large and deep holes at the base of waterfalls are called plunge pools. Incised or Entrenched Meanders In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel. Also, in the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes. Because of active lateral erosion, streams flowing over gentle slopes, develop sinuous or meandering courses. It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle. But very deep and wide meanders can also be found cut in hard rocks. Such meanders are called incised or entrenched meanders (Figure 6.2). River Terraces River terraces are surfaces marking old valley floor or floodplain levels. They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits. River terraces are basically products of erosion as they result due to vertical erosion by the stream into its own depositional floodplain. There can be a number of such terraces at different heights indicating former river bed levels. The river terraces may occur at the same elevation on either side of the rivers in which case they are called paired terraces.. DEPOSITIONAL LANDFORMS Alluvial Fans Alluvial fans (Figure 6.3) are formed when streams flowing from higher levels break into foot slope plains of low gradient. Normally very coarse load is carried by streams flowing over mountain slopes. This load becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a broad low to high cone shaped Rationalised-2023-24 50 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Deltas Deltas are like alluvial fans but develop at a different location. The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast, it spreads and accumulates as a low cone. Unlike in alluvial fans, the deposits making up deltas are very well sorted with clear stratification. The coarsest materials settle out first and the finer fractions like silts and clays are carried out into the sea. As the delta grows, the river distributaries continue to increase in length (Figure 6.4) and delta continues to build up into the sea. Floodplains, Natural Levees and Point Bars Deposition develops a floodplain just as erosion makes valleys. Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope. Thus, normally, fine sized materials like sand, silt and clay are carried by relatively slow moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed. A river bed made of river deposits is the active floodplain. The floodplain above the bank is inactive floodplain. Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits. In plains, channels shift laterally and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits. The flood deposits of spilled waters carry relatively finer materials like silt and clay. The flood plains in a delta are called delta plains. Figure 6.3 : An alluvial fan deposited by a hill stream on the way to Amarnath, Jammu and Kashmir deposit called alluvial fan. Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called distributaries. Alluvial fans in humid areas show normally low cones with gentle slope from head to toe and they appear as high cones with steep slope in arid and semi-arid climates. Figure 6.4 : A satellite view of part of Krishna river delta, Andhra Pradesh Figure 6.5 : Natural levee and point bars Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 51 Natural levees and point bars (Figure 6.5) are some of the important landforms found associated with floodplains. Natural levees are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds. Point bars are also known as meander bars. They are found on the concave side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank. They are almost uniform in profile and in width and contain mixed sizes of sediments. In what way do natural levees

differ from point bars? Meanders In large flood and delta plains, rivers rarely flow in straight courses. Loop-like channel patterns called meanders develop over flood and delta plains (Figure 6.6). the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside. If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the concave bank and undercutting along the convex bank. The concave bank is known as cut-off bank which shows up as a steep scarp and the convex bank presents a long, gentle profile (Figure 6.7). As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection points and are left as ox-bow lakes. GROUNDWATER Here the interest is not on groundwater as a resource. Our focus is on the work of groundwater in the erosion of landmasses and evolution of landforms. The surface water Figure 6.6 : A satellite scene showing meandering Burhi Gandak river near Muzaffarpur, Bihar, showing a number of oxbow lakes and cut-offs Meander is not a landform but is only a type of channel pattern. This is because of (i) propensity of water flowing over very gentle gradients to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the banks with many irregularities which can be used by water exerting pressure laterally; (iii) coriolis force acting on the fluid water deflecting it like it deflects the wind. When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally. Slight irregularities along Figure 6.7 : Meander growth and cut-off loops and slip-off and undercut banks Rationalised-2023-24 52 FUNDAMENTALS OF PHYSICAL GEOGRAPHY percolates well when the rocks are permeable, thinly bedded and highly jointed and cracked. After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves. It is this downward and horizontal movement of water which causes the rocks to erode. Physical or mechanical removal of materials by moving groundwater is insignificant in developing landforms. That is why, the results of the work of groundwater cannot be seen in all types of rocks. But in rocks like limestones or dolomites rich in calcium carbonate, the surface water as well as groundwater through the chemical process of solution and precipitation deposition develop varieties of landforms. These two processes of solution and precipitation are active in limestones or dolomites occurring either exclusively or interbedded with other rocks. Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called Karst topography after the typical topography developed in limestone rocks of Karst region in the Balkans adjacent to Adriatic sea. The karst topography is also characterised by erosional and depositional landforms. EROSIONAL LANDFORMS Pools, Sinkholes, Lapies and Limestone Pavements Small to medium sized round to sub-rounded shallow depressions called swallow holes form on the surface of limestones through solution. Sinkholes are very common in limestone/ karst areas. A sinkhole is an opening more or less circular at the top and funnel-shapped towards the bottom with sizes varying in area from a few sq. m to a hectare and with depth Figure 6.8 : Various karst features Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 53 from a less than half a metre to thirty metres or more. Some of these form solely through solution action (solution sinks) and others might start as solution forms first and if the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or a void below (collapse sinks). Quite often, sinkholes are covered up with soil mantle and appear as shallow water pools. Anybody stepping over such pools would go down like it happens in quicksands in deserts. The term doline is sometimes used to refer the collapse sinks. Solution sinks are more common than collapse sinks. Quite often the surface runoff simply goes down swallow and sink holes and flow as underground streams and reemerge at a distance downstream through a cave opening. When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, narrow to wide trenches called valley sinks or Uvalas form. Gradually, most of the surface of the limestone is eaten

away by these pits and trenches, leaving it extremely irregular with a maze of points, grooves and ridges or lapies. Especially, these ridges or lapies form due to differential solution activity along parallel to sub-parallel joints. The lapie field may eventually turn into somewhat smooth limestone pavements. Caves In areas where there are alternating beds of rocks (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds, cave formation is prominent. Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes. It is along these bedding planes that the limestone dissolves and long and narrow to wide gaps called caves result. There can be a maze of caves at different elevations depending upon the limestone beds and intervening rocks. Caves normally have an opening through which cave streams are discharged. Caves having openings at both the ends are called tunnels. Depositional Landforms Many depositional forms develop within the limestone caves. The chief chemical in limestone is calcium carbonate which is easily soluble in carbonated water (carbon dioxide absorbed rainwater). This calcium carbonate is deposited when the water carrying it in solution evaporates or loses its carbon dioxide as it trickles over rough rock surfaces. Stalactites, Stalagmites and Pillars Stalactites hang as icicles of different diameters. Normally they are broad at their bases and taper towards the free ends showing up in a variety of forms. Stalagmites rise up from the floor of the caves. In fact, stalagmites form due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it (Figure 6.9). Stalagmites may take the shape of a column, a disc, with either a smooth, rounded bulging end or a miniature crater like Figure 6.9 : Stalactites and stalagmites in limestone caves Rationalised-2023-24 54 FUNDAMENTALS OF PHYSICAL GEOGRAPHY depression. The stalagmite and stalactites eventually fuse to give rise to columns and pillars of different diameters. GLACIERS Masses of ice moving as sheets over the land (continental glacier or piedmont glacier if a vast sheet of ice is spread over the plains at the foot of mountains) or as linear flows down the slopes of mountains in broad trough-like valleys (mountain and valley glaciers) are called glaciers (Figure 6.10). The movement of glaciers is slow unlike water flow. The movement could be a few centimetres to a few metres a day or even less or more. Glaciers move basically because of the force of gravity. fragments) get dragged along the floors or sides of the valleys and cause great damage through abrasion and plucking. Glaciers can cause significant damage to even un-weathered rocks and can reduce high mountains into low hills and plains. As glaciers continue to move, debris gets removed, divides get lowered and eventually the slope is reduced to such an extent that glaciers will stop moving leaving only a mass of low hills and vast outwash plains along with other depositional features. Figures 6.11 and 6.12 show various glacial erosional and depositional forms described in the text. EROSIONAL LANDFORMS Cirque Cirques are the most common of landforms in glaciated mountains. The cirques quite often are found at the heads of glacial valleys. The accumulated ice cuts these cirques while moving down the mountain tops. They are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at its head as well as sides. A lake of water can be seen quite often within the cirques after the glacier disappears. Such lakes are called cirque or tarn lakes. There can be two or more cirques one leading into another down below in a stepped sequence. Horns and Serrated Ridges Horns form through head ward erosion of the cirque walls. If three or more radiating glaciers cut headward until their cirques meet, high, sharp pointed and steep sided peaks called horns form. The divides between cirque side walls or head walls get narrow because of progressive erosion and turn into serrated or saw-toothed ridges sometimes referred to as arêtes with very sharp crest and a zig-zag outline. The highest peak in the Alps, Matterhorn and the highest peak in the Himalayas, Everest are in fact horns formed through headward erosion of radiating cirques. Figure 6.10 : A glacier in its valley We have many glaciers in our country moving down the slopes and valleys in Himalayas. Higher reaches of Uttaranchal, Himachal Pradesh and Jammu and Kashmir, are places to see some of them. Do you know where one

can see river Bhagirathi is basically fed by meltwaters from under the snout (Gaumukh) of the Gangotri glacier. In fact, Alkapuri glacier feeds waters to Alakananda river. Rivers Alkananda and Bhagirathi join to make river Ganga near Deoprayag. Erosion by glaciers is tremendous because of friction caused by sheer weight of the ice. The material plucked from the land by glaciers (usually large-sized angular blocks and Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 55 Glacial Valleys/Troughs Glaciated valleys are trough-like and Ushaped with broad floors and relatively smooth, and steep sides. The valleys may contain littered debris or debris shaped as moraines with swampy appearance. There may be lakes gouged out of rocky floor or formed by debris within the valleys. There can be hanging valleys at an elevation on one or both sides of the main glacial valley. The faces of divides or spurs of such hanging valleys opening into main glacial valleys are quite often truncated to give them an appearance like triangular facets. Very deep glacial troughs filled with sea water and making up shorelines (in high latitudes) are called fjords/fiords. What are the basic differences between glacial valleys and river valleys? Depositional Landforms The unassorted coarse and fine debris dropped by the melting glaciers is called glacial till. Most of the rock fragments in till are angular to sub-angular in form. Streams form by melting ice at the bottom, sides or lower ends of glaciers. Some amount of rock debris small enough to be carried by such meltwater streams is washed down and deposited. Such glacio-fluvial deposits are called outwash deposits. Unlike till deposits, the outwash deposits are roughly stratified and assorted. The rock fragments in outwash deposits are somewhat rounded at their edges. Figure 6.12 shows a few depositional landforms commonly found in glaciated areas. Moraines They are long ridges of deposits of glacial till. Terminal moraines are long ridges of debris Figure 6.11 : Some glacial erosional and depositional forms (adapted and modified from Spencer, 1962) Rationalised-2023-24 56 FUNDAMENTALS OF PHYSICAL GEOGRAPHY deposited at the end (toe) of the glaciers. Lateral moraines form along the sides parallel to the glacial valleys. The lateral moraines may join a terminal moraine forming a horse-shoe shaped ridge (Fig. 6.11). There can be many lateral moraines on either side in a glacial valley. These moraines partly or fully owe their origin to glacio-fluvial waters pushing up materials to the sides of glaciers. Many valley glaciers retreating rapidly leave an irregular sheet of till over their valley floors. Such deposits varying greatly in thickness and in surface topography are called ground moraines. The moraine in the centre of the glacial valley flanked by lateral moraines is called medial moraine. They are imperfectly formed as compared to lateral moraines. Sometimes medial moraines are indistinguishable from ground moraines. Eskers When glaciers melt in summer, the water flows on the surface of the ice or seeps down along the margins or even moves through holes in the ice. These waters accumulate beneath the glacier and flow like streams in a channel beneath the ice. Such streams flow over the ground (not in a valley cut in the ground) with ice forming its banks. Very coarse materials like boulders and blocks along with some minor fractions of rock debris carried into this stream settle in the valley of ice beneath the glacier and after the ice melts can be found as a sinuous ridge called esker. Outwash Plains The plains at the foot of the glacial mountains or beyond the limits of continental ice sheets are covered with glacio-fluvial deposits in the form of broad flat alluvial fans which may join to form outwash plains of gravel, silt, sand and clay. Distinguish between river alluvial plains and glacial outwash plains. Drumlins Drumlins are smooth oval shaped ridge-like features composed mainly of glacial till with some masses of gravel and sand. The long axes of drumlins are parallel to the direction of ice movement. They may measure up to 1 Figure 6.12 : A panoramic diagram of glacial landscape with various depositional landforms (adapted and modified from Spencer, 1962) Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 57 km in length and 30 m or so in height. One end of the drumlins facing the glacier called the stoss end is blunter and steeper than the other end called tail. The drumlins form due to dumping of rock debris beneath heavily loaded ice through fissures in the glacier. The stoss end gets blunted due to pushing by moving ice. Drumlins give an indication of direction of glacier movement. What is the difference

between till and alluvium? WAVES AND CURRENTS Coastal processes are the most dynamic and hence most destructive. So, don't you think it is important to know about the coastal processes and forms? Some of the changes along the coasts take place very fast. At one place, there can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves. When waves break, the water is thrown with great force onto the shore, and simultaneously, there is a great churning of sediments on the sea bottom. Constant impact of breaking waves drastically affects the coasts. Storm waves and tsunami waves can cause far-reaching changes in a short period of time than normal breaking waves. As wave environment changes, the intensity of the force of breaking waves changes. Do you know about the generating forces behind waves and currents? If not, refer to the chapter on movements in ocean waters. Other than the action of waves, the coastal landforms depend upon (i) the configuration of land and sea floor; (ii) whether the coast is advancing (emerging) seaward or retreating (submerging) landward. Assuming sea level to be constant, two types of coasts are considered to explain the concept of evolution of coastal landforms: (i) high, rocky coasts (submerged coasts); (ii) low, smooth and gently sloping sedimentary coasts (emerged coasts). HIGH ROCKY COASTS Along the high rocky coasts, the rivers appear to have been drowned with highly irregular coastline. The coastline appears highly indented with extension of water into the land where glacial valleys (fjords) are present. The hill sides drop off sharply into the water. Shores do not show any depositional landforms initially. Erosion features dominate. Along high rocky coasts, waves break with great force against the land shaping the hill sides into cliffs. With constant pounding by waves, the cliffs recede leaving a wave-cut platform in front of the sea cliff. Waves gradually minimise the irregularities along the shore. The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments and roll to roundness, will get deposited in the offshore. After a considerable period of cliff development and retreat when coastline turns somewhat smooth, with the addition of some more material to this deposit in the offshore, a wave-built terrace would develop in front of wave-cut terrace. As the erosion along the coast takes place a good supply material becomes available to longshore currents and waves to deposit them as beaches along the shore and as bars (long ridges of sand and/ or shingle parallel to the coast) in the nearshore zone. Bars are submerged features and when bars show up above water, they are called barrier bars. Barrier bar which get keyed up to the headland of a bay is called a spit. When barrier bars and spits form at the mouth of a bay and block it, a lagoon forms. The lagoons would gradually get filled up by sediments from the land giving rise to a coastal plain. LOW SEDIMENTARY COASTS Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas. The coastline appears smooth with occasional incursions Rationalised-2023-24 58 FUNDAMENTALS OF PHYSICAL GEOGRAPHY of water in the form of lagoons and tidal creeks. The land slopes gently into the water. Marshes and swamps may abound along the coasts. Depositional features dominate. When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily building bars, barrier bars, spits and lagoons. Lagoons would eventually turn into a swamp which would subsequently turn into a coastal plain. The maintenance of these depositional features depends upon the steady supply of materials. Storm and tsunami waves cause drastic changes irrespective of supply of sediments. Large rivers which bring lots of sediments build deltas along low sedimentary coasts. The west coast of our country is a high rocky retreating coast. Erosional forms dominate in the west coast. The east coast of India is a low sedimentary coast. Depositional forms dominate in the east coast. What are the various differences between a high rocky coast and a low sedimentary coast in terms of processes and landforms? EROSIONAL LANDFORMS Cliffs, Terraces, Caves and Stacks Wave-cut cliffs and terraces are two forms usually found where erosion is the dominant shore process. Almost all sea cliffs are steep and may range from a few m to 30 m or even more. At the foot of such cliffs there may be a flat or gently sloping platform covered by rock debris derived from the sea cliff behind. Such platforms occurring at

elevations above the average height of waves is called a wavecut terrace. The lashing of waves against the base of the cliff and the rock debris that gets smashed against the cliff along with lashing waves create hollows and these hollows get widened and deepened to form sea caves. The roofs of caves collapse and the sea cliffs recede further inland. Retreat of the cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill are called sea stacks. Like all other features, sea stacks are also temporary and eventually coastal hills and cliffs will disappear because of wave erosion giving rise to narrow coastal plains, and with onrush of deposits from over the land behind may get covered up by alluvium or may get covered up by shingle or sand to form a wide beach. DEPOSITIONAL LANDFORMS Beaches and Dunes Beaches are characteristic of shorelines that are dominated by deposition, but may occur as patches along even the rugged shores. Most of the sediment making up the beaches comes from land carried by the streams and rivers or from wave erosion. Beaches are temporary features. The sandy beach which appears so permanent may be reduced to a very narrow strip of coarse pebbles in some other season. Most of the beaches are made up of sand sized materials. Beaches called shingle beaches contain excessively small pebbles and even cobbles. Just behind the beach, the sands lifted and winnowed from over the beach surfaces will be deposited as sand dunes. Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts. Bars, Barriers and Spits A ridge of sand and shingle formed in the sea in the off-shore zone lying approximately parallel to the coast is called an off-shore bar. An off-shore bar which is exposed due to further addition of sand is termed a barrier bar. The off-shore bars and barriers commonly form across the mouth of a river or at the entrance of a bay. Sometimes such barrier bars get keyed up to one end of the bay when they are called spits (Figure 6.13). Spits may also develop attached to headlands/hills. The barriers, bars and spits at the mouth of the bay gradually extend leaving only a small opening of the bay into the sea and the bay Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 59 will eventually develop into a lagoon. The lagoons get filled up gradually by sediment coming from the land or from the beach itself (aided by wind) and a broad and wide coastal plain may develop replacing a lagoon. are storm winds which are very destructive. Winds cause deflation, abrasion and impact. Deflation includes lifting and removal of dust and smaller particles from the surface of rocks. In the transportation process sand and silt act as effective tools to abrade the land surface. The impact is simply sheer force of momentum which occurs when sand is blown into or against a rock surface. It is similar to sand-blasting operation. The wind action creates a number of interesting erosional and depositional features in the deserts. In fact, many features of deserts owe their formation to mass wasting and running water as sheet floods. Though rain is scarce in deserts, it comes down torrentially in a short period of time. The desert rocks devoid of vegetation, exposed to mechanical and chemical weathering processes due to drastic diurnal temperature changes, decay faster and the torrential rains help in removing the weathered materials easily. That means, the weathered debris in deserts is moved by not only wind but also by rain/sheet wash. The wind moves fine materials and general mass erosion is accomplished mainly through sheet floods or sheet wash. Stream channels in desert areas are broad, smooth and indefinite and flow for a brief time after rains. EROSIONAL LANDFORMS Pediments and Pediplains Landscape evolution in deserts is primarily concerned with the formation and extension of pediments. Gently inclined rocky floors close to the mountains at their foot with or without a thin cover of debris, are called pediments. Such rocky floors form through the erosion of mountain front through a combination of lateral erosion by streams and sheet flooding. Erosion starts along the steep margins of the landmass or the steep sides of the tectonically controlled steep incision features over the landmass. Once, pediments are formed with a steep wash slope followed by cliff or free face above it, the steep wash slope and free face retreat backwards. This method WINDS Wind is one of the two dominant agents in hot deserts. The desert floors get heated up too much and too quickly because of being dry and barren. The heated

floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up eddies, whirlwinds, updrafts and downdrafts. Winds also move along the desert floors with great speed and the obstructions in their path create turbulence. Of course, there Do you know, the coastal off-shore bars offer the first buffer or defence against storm or tsunami by absorbing most of their destructive force. Then come the barriers, beaches, beach dunes and mangroves, if any, to absorb the destructive force of storm and tsunami waves. So, if we do anything which disturbs the 'sediment budget' and the mangroves along the coast, these coastal forms will get eroded away leaving human habitations to bear first strike of storm and tsunami waves. Figure 6.13 : A satellite picture of a part of Godavari river delta showing a spit Rationalised-2023-24 60 FUNDAMENTALS OF PHYSICAL GEOGRAPHY of erosion is termed as parallel retreat of slopes through backwasting. So, through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving an inselberg which is a remnant of the mountain. That's how the high relief in desert areas is reduced to low featureless plains called pediplains. Playas Plains are by far the most prominent landforms in the deserts. In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin. In times of sufficient water, this plain is covered up by a shallow water body. Such types of shallow lakes are called as playas where water is retained only for short duration due to evaporation and quite often the playas contain good deposition of salts. The playa plain covered up by salts is called alkali flats. Deflation Hollows and Caves Weathered mantle from over the rocks or bare soil, gets blown out by persistent movement of wind currents in one direction. This process may create shallow depressions called deflation hollows. Deflation also creates numerous small pits or cavities over rock surfaces. The rock faces suffer impact and abrasion of wind-borne sand and first shallow depressions called blow outs are created, and some of the blow outs become deeper and wider fit to be called caves. Mushroom, Table and Pedestal Rocks Many rock-outcrops in the deserts easily susceptible to wind deflation and abrasion are worn out quickly leaving some remnants of resistant rocks polished beautifully in the shape of mushroom with a slender stalk and a broad and rounded pear shaped cap above. Sometimes, the top surface is broad like a table top and quite often, the remnants stand out like pedestals. List the erosional features carved out by wind action and action of sheet floods. Depositional Landforms Wind is a good sorting agent. Depending upon the velocity of wind, different sizes of grains are moved along the floors by rolling or saltation and carried in suspension and in this process of transportation itself, the materials get sorted. When the wind slows or begins to die down, depending upon sizes of grains and their critical velocities, the grains will begin to settle. So, in depositional landforms made by wind, good sorting of grains can be found. Since wind is there everywhere and wherever there is good source of sand and with constant wind directions, depositional features in arid regions can develop anywhere. Sand Dunes Dry hot deserts are good places for sand dune formation. Obstacles to initiate dune formation are equally important. There can be a great variety of dune forms (Figure 6.14). Figure 6.14 : Various types of sand dunes Arrows indicate wind direction Rationalised-2023-24 LANDFORMS AND THEIR EVOLUTION 61 Crescent shaped dunes called barchans with the points or wings directed away from wind direction i.e., downwind, form where the wind direction is constant and moderate and where the original surface over which sand is moving is almost uniform. Parabolic dunes form when sandy surfaces are partially covered with vegetation. That means parabolic dunes are reversed barchans with wind direction being the same. Seif is similar to barchan with a small difference. Seif has only one wing or point. This happens when there is shift in wind conditions. The lone wings of seifs can grow very long and high. Longitudinal dunes form when supply of sand is poor and wind direction is constant. They appear as long ridges of considerable length but low in height. Transverse dunes are aligned perpendicular to wind direction. These dunes form when the wind direction is

constant and the source of sand is an elongated feature at right angles to the wind direction. They may be very long and low in height. When sand is plenty, quite often, the regular shaped dunes coalesce and lose their individual characteristics. Most of the dunes in the deserts shift and a few of them will get stabilised especially near human habitations. EXERCISES 1. Multiple choice questions. (i) In which of the following stages of landform development, downward cutting is dominated? (a) Youth stage (c) Early mature stage (b) Late mature stage (d) Old stage (ii) A deep valley characterised by steep step-like side slopes is known as (a) U-shaped valley (c) Blind valley (b) Gorge (d) Canyon (iii) In which one of the following regions the chemical weathering process is more dominant than the mechanical process? (a) Humid region (c) Arid region (b) Limestone region (d) Glacier region (iv) Which one of the following sentences best defines the term 'Lapies' ? (a) A small to medium sized shallow depression (b) A landform whose opening is more or less circular at the top and funnel shaped towards bottom (c) A landform formed due to dripping water from surface (d) An irregular surface with sharp pinnacles, grooves and ridges (v) A deep, long and wide trough or basin with very steep concave high walls at its head as well as in sides is known as: (a) Cirque (c) Lateral Moraine (b) Glacial valley (d) Esker 2. Answer the following questions in about 30 words. (i) What do incised meanders in rocks and meanders in plains of alluvium indicate? Rationalised-2023-24 62 FUNDAMENTALS OF PHYSICAL GEOGRAPHY (ii) Explain the evolution of valley sinks or uvalas. (iii) Underground flow of water is more common than surface run-off in limestone areas. Why? (iv) Glacial valleys show up many linear depositional forms. Give their locations and names. (v) How does wind perform its task in desert areas? Is it the only agent responsible for the erosional features in the deserts? 3. Answer the following questions in about 150 words. (i) Running water is by far the most dominating geomorphic agent in shaping the earth's surface in humid as well as in arid climates. Explain. (ii) Limestones behave differently in humid and arid climates. Why? What is the dominant and almost exclusive geomorphic process in limestone areas and what are its results? (iii) How do glaciers accomplish the work of reducing high mountains into low hills and plains? Project Work Identify the landforms, materials and processes around your area. Rationalised-2023-24CLIMATE This unit deals with • Atmosphere — compositions and structure; elements of weather and climate • Insolation — angle of incidence and distribution; heat budget of the earth — heating and cooling of atmosphere (conduction, convection, terrestrial radiation, advection); temperature — factors controlling temperature; distribution of temperature — horizontal and vertical; inversion of temperature • Pressure — pressure belts; winds-planetary seasonal and local, air masses and fronts; tropical and extra tropical cyclones • Precipitation — evaporation; condensation — dew, frost, fog, mist and cloud; rainfall — types and world distributon • World climates — classification (Koeppen), greenhouse effect, global warming and climatic changes UNIT IV Rationalised-2023-24 COMPOSITION AND STRUCTURE OF ATMOSPHERE C an a person live without air? We eat food two - three times a day and drink water more frequently but breathe every few seconds. Air is essential to the survival of all organisms. Some organisms like humans may survive for some time without food and water but can't survive even a few minutes without breathing air. That shows the reason why we should understand the atmosphere in greater detail. Atmosphere is a mixture of different gases and it envelopes the earth all round. It contains life-giving gases like oxygen for humans and animals and carbon dioxide for plants. The air is an integral part of the earth's mass and 99 per cent of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface. The air is colourless and odourless and can be felt only when it blows as wind. Can you imagine what will happen to us in the absence of ozone in the atmosphere? COMPOSITION OF THE ATMOSPHERE The atmosphere is composed of gases, water vapour and dust particles. The proportion of gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost in negligible quantity at the height of 120 km. Similarly, carbon dioxide and water vapour are found only up to 90 km from the surface of the earth. Gases Carbon dioxide is meteorologically a very important gas as it is

transparent to the incoming solar radiation but opaque to the outgoing terrestrial radiation. It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface. It is largely responsible for the green house effect. The volume of other gases is constant but the volume of carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels. This has also increased the temperature of the air. Ozone is another important component of the atmosphere found between 10 and 50 km above the earth's surface and acts as a filter and absorbs the ultra-violet rays radiating from the sun and prevents them from reaching the surface of the earth. Water Vapour Water vapour is also a variable gas in the atmosphere, which decreases with altitude. In the warm and wet tropics, it may account for four per cent of the air by volume, while in the dry and cold areas of desert and polar regions, it may be less than one per cent of the air. Water vapour also decreases from the equator towards the poles. It also absorbs parts of the insolation from the sun and preserves the earth's radiated heat. It thus, acts like a blanket allowing the earth neither to become too cold nor too hot. Water vapour also contributes to the stability and instability in the air. CHAPTER Rationalised-2023-24 COMPOSITION AND STRUCTURE OF ATMOSPHERE 65 Dust Particles Atmosphere has a sufficient capacity to keep small solid particles, which may originate from different sources and include sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors. Dust particles are generally concentrated in the lower layers of the atmosphere; yet, convectional air currents may transport them to great heights. The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions. Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds. STRUCTURE OF THE ATMOSPHERE The atmosphere consists of different layers with varying density and temperature. Density is highest near the surface of the earth and decreases with increasing altitude. The column of atmosphere is divided into five different layers depending upon the temperature condition. They are: troposphere, stratosphere, mesosphere, thermosphere and exosphere. The troposphere is the lowermost layer of the atmosphere. Its average height is 13 km and extends roughly to a height of 8 km near the poles and about 18 km at the equator. Thickness of the troposphere is greatest at the equator because heat is transported to great heights by strong convectional currents. This layer contains dust particles and water vapour. All changes in climate and weather take place in this layer. The temperature in this layer decreases at the rate of 1 C for every 165m of height. This is the most important layer for all biological activity. The zone separating the tropsophere from stratosphere is known as the tropopause. The air temperature at the tropopause is about minus 800C over the equator and about minus 45oC over the poles. The temperature here is nearly constant, and hence, it is called the tropopause. The stratosphere is found above the tropopause and extends up to a height of 50 km. One important feature of the stratosphere is that it contains the ozone layer. This layer absorbs ultra-violet radiation and shields life on the earth from intense, harmful form of energy. The mesosphere lies above the stratosphere, which extends up to a height of 80 km. In this layer, once again, temperature starts decreasing with the increase in altitude and reaches up to minus 100 C at the height of 80 km. The upper limit of mesosphere is known as the mesopause. The ionosphere is located between 80 and 400 km above the mesopause. It contains electrically charged particles known as ions, and hence, it is known as ionosphere. Radio waves transmitted from the earth are reflected back to the earth by this layer. Temperature here starts increasing with height. The uppermost layer of the atmosphere above the thermosphere Figure 7.1 : Structure of atmosphere Rationalised-2023-24 66 FUNDAMENTALS OF PHYSICAL GEOGRAPHY is known as the exosphere. This is the highest layer but very little is known about it. Whatever contents are there, these are extremely rarefied in this layer, and it gradually merges with the outer space. Although all layers of the atmosphere must be exercising influence on us, geographers are concerned with the first two layers of the atmosphere. EXERCISES 1. Multiple choice questions. (i) Which one of the following

gases constitutes the major portion of the atmosphere? (a) Oxygen (c) Argon (b) Nitrogen (d) Carbon dioxide (ii) Atmospheric layer important for human beings is: (a) Stratosphere (c) Troposphere (b) Mesosphere (d) Ionosphere (iii) Sea salt, pollen, ash, smoke soot, fine soil — these are associated with: (a) Gases (c) Water vapour (b) Dust particles (d) Meteors (iv) Oxygen gas is in negligible quantity at the height of atmosphere: (a) 90 km (c) 100 km (b) 120 km (d) 150 km (v) Which one of the following gases is transparent to incoming solar radiation and opaque to outgoing terrestrial radiation? (a) Oxygen (c) Helium (b) Nitrogen (d) Carbon dioxide 2. Answer the following questions in about 30 words. (i) What do you understand by atmosphere? (ii) What are the elements of weather and climate? (iii) Describe the composition of atmosphere. (iv) Why is troposphere the most important of all the layers of the atmosphere? 3. Answer the following questions in about 150 words. (i) Describe the composition of the atmosphere. (ii) Draw a suitable diagram for the structure of the atmosphere and label it and describe it. Elements of Weather and Climate The main elements of atmosphere which are subject to change and which influence human life on earth are temperature, pressure, winds, humidity, clouds and precipitation. These elements have been dealt in detail in Chapters 8, 9 and 10. Rationalised-2023-24SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE D o you feel air around you? Do you know that we live at the bottom of a huge pile of air? We inhale and exhale but we feel the air when it is in motion. It means air in motion is wind. You have already learnt about the fact that earth is surrounded by air all around. This envelop of air is atmosphere which is composed of numerous gases. These gases support life over the earth's surface. The earth receives almost all of its energy from the sun. The earth in turn radiates back to space the energy received from the sun. As a result, the earth neither warms up nor does it get cooled over a period of time. Thus, the amount of heat received by different parts of the earth is not the same. This variation causes pressure differences in the atmosphere. This leads to transfer of heat from one region to the other by winds. This chapter explains the process of heating and cooling of the atmosphere and the resultant temperature distribution over the earth's surface. SOLAR RADIATION The earth's surface receives most of its energy in short wavelengths. The energy received by the earth is known as incoming solar radiation which in short is termed as insolation. As the earth is a geoid resembling a sphere, the sun's rays fall obliquely at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy. On an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere. The solar output received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the sun. During its revolution around the sun, the earth is farthest from the sun (152 million km) on 4th July. This position of the earth is called aphelion. On 3rd January, the earth is the nearest to the sun (147 million km). This position is called perihelion. Therefore, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July. However, the effect of this variation in the solar output is masked by other factors like the distribution of land and sea and the atmospheric circulation. Hence, this variation in the solar output does not have great effect on daily weather changes on the surface of the earth. Variability of Insolation at the Surface of the Earth The amount and the intensity of insolation vary during a day, in a season and in a year. The factors that cause these variations in insolation are : (i) the rotation of earth on its axis; (ii) the angle of inclination of the sun's rays; (iii) the length of the day; (iv) the transparency of the atmosphere; (v) the configuration of land in terms of its aspect. The last two however, have less influence. The fact that the earth's axis makes an angle of 66½ with the plane of its orbit round the sun has a greater influence on the amount of insolation received at different latitudes. The second factor that determines the amount of insolation received is the angle of CHAPTER Rationalised-2023-24 68 FUNDAMENTALS OF PHYSICAL GEOGRAPHY inclination of the rays. This depends on the latitude of a place. The higher the latitude the less is the angle they make with the surface of the earth resulting in slant sun rays. The area covered by vertical rays is always less than the slant rays. If more area is

covered, the energy gets distributed and the net energy received per unit area decreases. Moreover, the slant rays are required to pass through greater depth of the atmosphere resulting in more absorption, scattering and diffusion. The Passage of Solar Radiation through the Atmosphere The atmosphere is largely transparent to short wave solar radiation. The incoming solar radiation passes through the atmosphere before striking the earth's surface. Within the troposphere water vapour, ozone and other gases absorb much of the near infrared radiation. Very small-suspended particles in the troposphere scatter visible spectrum both to the space and towards the earth surface. This process adds colour to the sky. The red colour of the rising and the setting sun and the blue colour of the sky are the result of scattering of light within the atmosphere. Spatial Distribution of Insolation at the Earth's Surface The insolation received at the surface varies from about 320 Watt/m2 in the tropics to about 70 Watt/m2 in the poles. Maximum insolation is received over the subtropical deserts, where the cloudiness is the least. Equator receives comparatively less insolation than the tropics. Generally, at the same latitude the insolation is more over the continent than over the oceans. In winter, the middle and higher latitudes receive less radiation than in summer. HEATING AND COOLING OF ATMOSPHERE There are different ways of heating and cooling of the atmosphere. The earth after being heated by insolation transmits the heat to the atmospheric layers near to the earth in long wave form. The air in contact with the land gets heated slowly and the upper layers in contact with the lower layers also get heated. This process is called conduction. Conduction takes place when two bodies of unequal temperature are in contact with one another, there is a flow of energy from the warmer to cooler body. The transfer of heat continues until both the bodies attain the same temperature or the contact is broken. Conduction is important in heating the lower layers of the atmosphere. The air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmsphere. This process of vertical heating of the atmosphere is known as convection. The convective transfer of energy is confined only to the troposphere. The transfer of heat through horizontal movement of air is called advection. Horizontal movement of the air is relatively more important than the vertical movement. In middle latitudes, most of dirunal (day and night) variation in daily weather are caused by advection alone. In tropical regions particularly in northern India during summer season local winds called 'loo' is the outcome of advection process. Terrestrial Radiation The insolation received by the earth is in short waves forms and heats up its surface. The Figure 8.1 : Summer Solstice Rationalised-2023-24 SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE 69 the earth surface. Roughly 35 units are reflected back to space even before reaching the earth's surface. Of these, 27 units are reflected back from the top of the clouds and 2 units from the snow and ice-covered areas of the earth. The reflected amount of radiation is called the albedo of the earth. The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth's surface. The earth radiates back 51 units in the form of terrestrial radiation. Of these, 17 units are radiated to space directly and the remaining 34 units are absorbed by the atmosphere (6 units absorbed directly by the atmosphere, 9 units through convection and turbulence and 19 units through latent heat of condensation). 48 units absorbed by the atmosphere (14 units from insolation +34 units from terrestrial radiation) are also radiated back into space. Thus, the total radiation returning from the earth and the atmosphere respectively is 17+48=65 units which balance the total of 65 units received from the sun. This is termed the heat budget or heat balance of the earth. This explains, why the earth neither warms up nor cools down despite the huge transfer of heat that takes place. earth after being heated itself becomes a radiating body and it radiates energy to the atmosphere in long wave form. This energy heats up the atmosphere from below. This process is known as terrestrial radiation. The long wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and the other green house gases. Thus, the atmosphere is indirectly heated by the earth's radiation. The atmosphere in turn radiates and transmits heat to the space. Finally the amount of heat received from the sun is returned to space,

thereby maintaining constant temperature at the earth's surface and in the atmosphere. Heat Budget of the Planet Earth Figure 9.2 depicts the heat budget of the planet earth. The earth as a whole does not accumulate or loose heat. It maintains its temperature. This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation. Consider that the insolation received at the top of the atmosphere is 100 per cent. While passing through the atmosphere some amount of energy is reflected, scattered and absorbed. Only the remaining part reaches Figure 8.2 : Heat budget of the earth Rationalised-2023-24 70 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Variation in the Net Heat Budget at the Earth's Surface As explained earlier, there are variations in the amount of radiation received at the earth's surface. Some part of the earth has surplus radiation balance while the other part has deficit. Figure 8.3 depicts the latitudinal variation in the net radiation balance of the earth — the atmosphere system. The figure shows that there is a surplus of net radiation balance between 40 degrees north and south and the regions near the poles have a deficit. The surplus heat energy from the tropics is redistributed pole wards and as a result the tropics do not get progressively heated up due to the accumulation of excess heat or the high latitudes get permanently frozen due to excess deficit. Figure 8.3 : Latitudinal variation in net radiation balance the sea, the air-mass circulation; (iv) the presence of warm and cold ocean currents; (v) local aspects. The latitude : The temperature of a place depends on the insolation received. It has been explained earlier that the insolation varies according to the latitude hence the temperature also varies accordingly. The altitude : The atmosphere is indirectly heated by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations. In other words, the temperature generally decreases with increasing height. The rate of decrease of temperature with height is termed as the normal lapse rate. It is 6.5°C per 1,000 m. Distance from the sea : Another factor that influences the temperature is the location of a place with respect to the sea. Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly. Therefore, the variation in temperature over the sea is less compared to land. The places situated near the sea come under the moderating influence of the sea and land breezes which moderate the temperature. Air-mass and Ocean currents : Like the land and sea breezes, the passage of air masses also affects the temperature. The places, which come under the influence of warm airmasses experience higher temperature and the places that come under the influence of cold air-masses experience low temperature. Similarly, the places located on the coast where the warm ocean currents flow record higher temperature than the places located on the coast where the cold currents flow. Distribution of Temperature The global distribution of temperature can well be understood by studying the temperature distribution in January and July. The temperature distribution is generally Temperature The interaction of insolation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature. While heat represents the molecular movement of particles comprising a substance, the temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is. Factors Controlling Temperature Distribution The temperature of air at any place is influenced by (i) the latitude of the place; (ii) the altitude of the place; (iii) distance from Rationalised-2023-24 SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE 71 shown on the map with the help of isotherms. The Isotherms are lines joining places having equal temperature. Figure 8.4 (a) and (b) show the distribution of surface air temperature in the month of January and July. In general the effect of the latitude on temperature is well pronounced on the map, as the isotherms are generally parallel to the latitude. The deviation from this general trend is more pronounced in January than in July, especially in the northern hemisphere. In the northern hemisphere the land surface area is much larger than in the southern hemisphere. Hence, the effects of land mass and the ocean currents are well pronounced. In January the isotherms deviate to the north over the ocean and to the south over the continent. This can be seen on the North Atlantic Ocean. The presence of

warm ocean currents, Gulf Stream and North Atlantic drift, make the Northern Atlantic Ocean warmer and the isotherms bend towards the north. Over the land the temperature decreases sharply and the isotherms bend towards south in Europe. It is much pronounced in the Siberian plain. The mean January temperature along 60° E longitude is minus 20° C both at 80° N and 50 N latitudes. The mean monthly temperature for January is over 27° C, in equatorial oceans over 24° C in the tropics and 2° C - 0° C in the middle latitudes and –18° C to –48° C in the Eurasian continental interior. The effect of the ocean is well pronounced in the southern hemisphere. Here the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere. The isotherm of 20° C, 10° C, and 0° C runs parallel to 35° S, 45° S and 60° S latitudes respectively. In July the isotherms generally run parallel to the latitude. The equatorial oceans record warmer temperature, more than 27°C. Figure 8.4 (a) : The distribution of surface air temperature in the month of January Rationalised-2023-24 72 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Figure 8.5 : The range of temperature between January and July Figure 8.4 (b) : The distribution of surface air temperature in the month of July Rationalised-2023-24 SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE 73 Over the land more than 30°C is noticed in the subtropical continental region of Asia, along the 30° N latitude. Along the 40° N runs the isotherm of 10° C and along the 40 S the temperature is 10° C. Figure 8.5 shows the range of temperature between January and July. The highest range of temperature is more than 60 C over the north-eastern part of Eurasian continent. This is due to continentality. The least range of temperature, 3°C, is found between 20° S and 15° N. INVERSION OF TEMPERATURE Normally, temperature decreases with increase in elevation. It is called normal lapse rate. At times, the situations is reversed and the normal lapse rate is inverted. It is called Inversion of temperature. Inversion is usually of short duration but quite common nonetheless. A long winter night with clear skies and still air is ideal situation for inversion. The heat of the day is radiated off during the night, and by early morning hours, the earth is cooler than the air above. Over polar areas, temperature inversion is normal throughout the year. Surface inversion promotes stability in the lower layers of the atmosphere. Smoke and dust particles get collected beneath the inversion layer and spread horizontally to fill the lower strata of the atmosphere. Dense fogs in mornings are common occurrences especially during winter season. This inversion commonly lasts for few hours until the sun comes up and beings to warm the earth. The inversion takes place in hills and mountains due to air drainage. Cold air at the hills and mountains, produced during night, flows under the influence of gravity. Being heavy and dense, the cold air acts almost like water and moves down the slope to pile up deeply in pockets and valley bottoms with warm air above. This is called air drainage. It protects plants from frost damages. l Plank's law states that hotter a body, the more energy it will radiate and shorter the wavelength of that radiation. l Specific heat is the energy needed to raise the temperature of one gram of substance by one Celsius. EXERCISES 1. Multiple choice questions. (i) The sun is directly overhead at noon on 21st June at: (a) The equator (c) 23.5° N (b) 23.5° S (d) 66.5° N (ii) In which one of the following cities, are the days the longest? (a) Tiruvanantpuram (c) Hyderabad (b) Chandigarh (d) Nagpur (iii) The atmosphere is mainly heated by the: (a) Short wave solar radiation (c) Long wave terrestrial radiation (b) Reflected solar radiation (d) Scattered solar radiation Rationalised-2023-24 74 FUNDAMENTALS OF PHYSICAL GEOGRAPHY (iv) Make correct pairs from the following two columns. (i) Insolation (a) The difference between the mean temperature of the warmest and the coldest months (ii) Albedo (b) The lines joining the places of equal temperature (iii) Isotherm (c) The incoming solar radiation (iv) Annual range (d) The percentage of visible light reflected by an object (v) The main reason that the earth experiences highest temperatures in the subtropics in the northern hemisphere rather than at the equator is : (a) Subtropical areas tend to have less cloud cover than equatorial areas. (b) Subtropical areas have longer day hours in the summer than the equatorial. (c) Subtropical areas have an enhanced "green house effect" compared to equatorial areas. (d) Subtropical areas are nearer to the

oceanic areas than the equatorial locations. 2. Answer the following questions in about 30 words. (i) How does the unequal distribution of heat over the planet earth in space and time cause variations in weather and climate? (ii) What are the factors that control temperature distribution on the surface of the earth? (iii) In India, why is the day temperature maximum in May and why not after the summer solstice? (iv) Why is the annual range of temperature high in the Siberian plains? 3. Answer the following questions in about 150 words. (i) How do the latitude and the tilt in the axis of rotation of the earth affect the amount of radiation received at the earth's surface? (ii) Discuss the processes through which the earth-atmosphere system maintains heat balance. (iii) Compare the global distribution of temperature in January over the northern and the southern hemisphere of the earth. Project Work Select a meteorological observatory located in your city or near your town. Tabulate the temperature data as given in the climatological table of observatories : (i) Note the altitude, latitude of the observatory and the period for which the mean is calculated. (ii) Define the terms related to temperature as given in the table. (iii) Calculate the daily mean monthly temperature. Rationalised-2023-24 SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE 75 (iv) Draw a graph to show the daily mean maximum, the daily mean minimum and the mean temperature. (v) Calculate the annual range of temperature. (vi) Find out in which months the daily range of temperature is the highest and the lowest. (vii) List out the factors that determine the temperature of the place and explain the possible causes for temperature variation in the months of January, May, July and October. Example Observatory : New Delhi (Safdarjung) Latitude : 28°35°' N Based on observations : 1951 - 1980 Altitude above mean sea level : 216 m Month Mean of Mean of Highest Lowest Daily Daily Recorded Recorded Max.(°C) Min.(°C) (°C) (°C) January 21.1 7.3 29.3 0.6 May 39.6 25.9 47.2 17.5 Daily mean monthly temperature January 21.1+7.3 O = 14.2 C 2 May 39.6+25.9 O = 32.75 C 2 Annual range of temperature Mean Max. Temperature in May - Mean Temperature in January Annual range of temperature = 32.75°C – 14.2°C = 18.55°C Rationalised-2023-24ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS E arlier Chapter 8 described the uneven distribution of temperature over the surface of the earth. Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure. The result is that it causes the movement of air from high pressure to low pressure, setting the air in motion. You already know that air in horizontal motion is wind. Atmospheric pressure also determines when the air will rise or sink. The wind redistributes the heat and moisture across the planet, thereby, maintaining a constant temperature for the planet as a whole. The vertical rising of moist air cools it down to form the clouds and bring precipitation. This chapter has been devoted to explain the causes of pressure differences, the forces that control the atmospheric circulation, the turbulent pattern of wind, the formation of air masses, the disturbed weather when air masses interact with each other and the phenomenon of violent tropical storms. ATMOSPHERIC PRESSURE Do you realise that our body is subjected to a lot of air pressure. As one moves up the air gets varified and one feels breathless. The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the atmospheric pressure. The atmospheric pressure is expressed in units of milibar. At sea level the average atmospheric pressure is 1,013.2 milibar. Due to gravity the air at the surface is denser and hence has higher pressure. Air pressure is measured with the help of a mercury barometer or the aneroid barometer. Consult your book, Practical Work in Geography — Part I (NCERT, 2006) and learn about these instruments. The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas. Vertical Variation of Pressure In the lower atmosphere the pressure decreases rapidly with height. The decrease amounts to about 1 mb for each 10 m increase in elevation. It does not always decrease at the same rate. Table 9.1 gives the average pressure and temperature at selected levels of elevation for a standard atmosphere. Table 9.1 : Standard Pressure and Temperature at Selected Levels Level Pressure in mb Temperature °C Sea Level 1,013.25 15.2 1 km

898.76 8.7 5 km 540.48 –17. 3 10 km 265.00 – 49.7 The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But, it is generally balanced by a nearly equal but opposite gravitational force. Hence, we do not experience strong upward winds. CHAPTER Rationalised-2023-24 ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS 77 Horizontal Distribution of Pressure Small differences in pressure are highly significant in terms of the wind direction and purposes of comparison. The sea level pressure distribution is shown on weather maps. Figure 9.1 shows the patterns of isobars corresponding to pressure systems. Lowpressure system is enclosed by one or more isobars with the lowest pressure in the centre. High-pressure system is also enclosed by one or more isobars with the highest pressure in the centre. World Distribution of Sea Level Pressure The world distribution of sea level pressure in January and July has been shown in Figures 9.2 and 9.3. Near the equator the sea level pressure is low and the area is known as equatorial low. Along 30° N and 30o S are found the high-pressure areas known as the subtropical highs. Further pole wards along 60o N and 60o S, the low-pressure belts are termed as the sub polar lows. Near the poles the pressure is high and it is known as the polar high. These pressure belts are not permanent Figure 9.2 : Distribution of pressure (in millibars) — January Figure 9.1 : Isobars, pressure and wind systems in Northern Hemisphere velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels. Isobars are lines connecting places having equal pressure. In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for Rationalised-2023-24 78 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Pressure Gradient Force The differences in atmospheric pressure produces a force. The rate of change of pressure with respect to distance is the pressure gradient. The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart. Frictional Force It affects the speed of the wind. It is greatest at the surface and its influence generally extends upto an elevation of 1 - 3 km. Over the sea surface the friction is minimal. Coriolis Force The rotation of the earth about its axis affects the direction of the wind. This force is called the Coriolis force after the French physicist who described it in 1844. It deflects the wind to the right direction in the northern hemisphere and in nature. They oscillate with the apparent movement of the sun. In the northern hemisphere in winter they move southwards and in the summer northwards. Forces Affecting the Velocity and Direction of Wind You already know that the air is set in motion due to the differences in atmospheric pressure. The air in motion is called wind. The wind blows from high pressure to low pressure. The wind at the surface experiences friction. In addition, rotation of the earth also affects the wind movement. The force exerted by the rotation of the earth is known as the Coriolis force. Thus, the horizontal winds near the earth surface respond to the combined effect of three forces – the pressure gradient force, the frictional force and the Coriolis force. In addition, the gravitational force acts downward. Figure 9.3 : Distribution of pressure (in millibars) — July Rationalised-2023-24 ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS 79 to the left in the southern hemisphere. The deflection is more when the wind velocity is high. The Coriolis force is directly proportional to the angle of latitude. It is maximum at the poles and is absent at the equator. The Coriolis force acts perpendicular to the pressure gradient force. The pressure gradient force is perpendicular to an isobar. The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind. As a result of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it. At the equator, the Coriolis force is zero and the wind blows perpendicular to the isobars. The low pressure gets filled instead of getting intensified. That is the reason why tropical cyclones are not formed near the equator. Pressure and Wind The velocity and direction of the wind are the net result of the wind generating forces. The winds in the upper atmosphere, 2 - 3 km above the surface, are free from frictional effect of the surface and are controlled mainly by the pressure gradient and the Coriolis force. When isobars are straight and when there is no friction, the pressure gradient force is

balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the geostrophic wind (Figure 9.4). Table 9.2 : Pattern of Wind Direction in Cyclones and Anticyclones Pressure System Pressure Condition Pattern of Wind Direction at the Centre Northern Hemisphere Southern Hemisphere Cyclone Low Anticlockwise Clockwise Anticyclone High Clockwise Anticlockwise The wind circulation around a low is called cyclonic circulation. Around a high it is called anti cyclonic circulation. The direction of winds around such systems changes according to their location in different hemispheres (Table 9.2). The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level. Generally, over low pressure area the air will converge and rise. Over high pressure area the air will subside from above and diverge at the surface (Figure 9.5). Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation. Figure 9.4 : Geostropic Wind General circulation of the atmosphere The pattern of planetary winds largely depends on : (i) latitudinal variation of atmospheric heating; (ii) emergence of pressure belts; (iii) the migration of belts following apparent path of the sun; (iv) the distribution of continents and oceans; (v) the rotation of earth. The pattern of the movement of the planetary winds is called the general circulation of the atmosphere. The general circulation of the atmosphere also sets in motion the ocean water circulation which influences the earth's Figure 9.5 : Convergence and divergence of winds Rationalised-2023-24 80 FUNDAMENTALS OF PHYSICAL GEOGRAPHY climate. A schematic description of the general circulation is shown in Figure 9.6. The general circulation of the atmosphere also affects the oceans. The large-scale winds of the atmosphere initiate large and slow moving currents of the ocean. Oceans in turn provide input of energy and water vapour into the air. These interactions take place rather slowly over a large part of the ocean. General Atmospheric Circulation and its Effects on Oceans Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation. The warm water of the central Pacific Ocean slowly drifts towards South American coast and replaces the cool Peruvian current. Such appearance of warm water off the coast of Peru is known as the El Nino. The El Nino event is closely associated with the pressure changes in the Central Pacific and Australia. This change in pressure condition over Pacific is known as the southern oscillation. The combined phenomenon of southern oscillation and El Nino is known as ENSO. In the years when the ENSO is strong, large-scale variations in weather occur over the world. The arid west coast of South America receives heavy rainfall, drought occurs in Australia and sometimes in India and floods in China. This phenomenon is closely monitored and is used for long range forecasting in major parts of the world. Seasonal Wind The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts. The most pronounced effect of such a shift is noticed in the monsoons, especially over southeast Asia. You would be studying the details of monsoon in the book India : Physical Environment (NCERT, 2006). The other local deviations from the general circulation system are as follows. Local Winds Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds. Figure 9. 6 : Simplified general circulation of the atmosphere The air at the Inter Tropical Convergence Zone (ITCZ) rises because of convection caused by high insolation and a low pressure is created. The winds from the tropics converge at this low pressure zone. The converged air rises along with the convective cell. It reaches the top of the troposphere up to an altitude of 14 km. and moves towards the poles. This causes accumulation of air at about 30o N and S. Part of the accumulated air sinks to the ground and forms a subtropical high. Another reason for sinking is the cooling of air when it reaches 30o N and S latitudes. Down below near the land surface the air flows towards the equator as the easterlies. The easterlies from either side of the equator converge in the Inter Tropical Convergence Zone (ITCZ). Such circulations from the surface upwards and vice-versa are called cells. Such a cell in the tropics is called Hadley

Cell. In the middle latitudes the circulation is that of sinking cold air that comes from the poles and the rising warm air that blows from the subtropical high. At the surface these winds are called westerlies and the cell is known as the Ferrel cell. At polar latitudes the cold dense air subsides near the poles and blows towards middle latitudes as the polar easterlies. This cell is called the polar cell. These three cells set the pattern for the general circulation of the atmosphere. The transfer of heat energy from lower latitudes to higher latitudes maintains the general circulation. Rationalised-2023-24 ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS 81 Land and Sea Breezes As explained earlier, the land and sea absorb and transfer heat differently. During the day the land heats up faster and becomes warmer than the sea. Therefore, over the land the air rises giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high. Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze. In the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze results (Figure 9.7). Figure 9.7 : Land and sea breezes Mountain and Valley Winds In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the valley breeze. During the night the slopes get cooled and the dense air descends into the valley as the mountain wind. The cool air, of the high plateaus and ice fields draining into the valley is called katabatic wind. Another type of warm wind occurs on the leeward side of the mountain ranges. The moisture in these winds, while crossing the mountain ranges condense and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by adiabatic process. This dry air may melt the snow in a short time. Air Masses When the air remains over a homogenous area for a sufficiently longer time, it acquires the characteristics of the area. The homogenous regions can be the vast ocean surface or vast plains. The air with distinctive characteristics in terms of temperature and humidity is called an airmass. It is defined as a large body of air having little horizontal variation in temperature and moisture. The homogenous surfaces, over which air masses form, are called the source regions. The air masses are classified according to the source regions. There are five major source regions. These are: (i) Warm tropical and subtropical oceans; (ii) The subtropical hot deserts; (iii) The relatively cold high latitude oceans; (iv) The very cold snow covered continents in high latitudes; (v) Permanently ice covered continents in the Arctic and Antarctica. Accordingly, following types of airmasses are recognised: (i) Maritime tropical (mT); (ii) Continental tropical (cT); (iii) Maritime polar (mP); (iv) Continental polar (cP); (v) Continental arctic (cA). Tropical air masses are warm and polar air masses are cold. Fronts When two different air masses meet, the boundary zone between them is called a front. The process of formation of the fronts is known as frontogenesis. There are four types of fronts: (a) Cold; (b) Warm; (c) Stationary; (d) Occluded. When the front remains stationary, it is called a stationary front. When the cold air moves Rationalised-2023-24 82 FUNDAMENTALS OF PHYSICAL GEOGRAPHY towards the warm air mass, its contact zone is called the cold front, whereas if the warm air mass moves towards the cold air mass, the contact zone is a warm front. If an air mass is fully lifted above the land surface, it is called the occluded front. The fronts occur in middle latitudes and are characterised by steep gradient in temperature and pressure. They bring abrupt changes in temperature and cause the air to rise to form clouds and cause precipitation. Extra Tropical Cyclones The systems developing in the mid and high latitude, beyond the tropics are called the middle latitude or extra tropical cyclones. The passage of front causes abrupt changes in the weather conditions over the area in the middle and high latitudes. Extra tropical cyclones form along the polar front. Initially, the front is stationary. In the northern hemisphere, warm air blows from the south and cold air from the north of the front. When the pressure drops along the front, the warm air moves northwards and the cold air move towards, south setting in motion an anticlockwise cyclonic circulation. The cyclonic circulation leads to a well developed extra tropical cyclone, with a

warm front and a cold front. The plan and cross section of a well developed cyclone is given in Figure 9.9. There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector. The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation. The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front. The cold front moves faster than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is occluded and the cyclone dissipates. The processes of wind circulation both at the surface and aloft are closely interlinked. The extra tropical cyclone differs from the tropical cyclone in number of ways. The extra tropical cyclones have a clear frontal system Figure 9.8 : Vertical Sections of : (a) Warm Front; (b) Cold Front; (c) Occluded Front Figure 9. 9 : Extra tropical cyclones Rationalised-2023-24 ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS 83 which is not present in the tropical cyclones. They cover a larger area and can originate over the land and sea. Whereas the tropical cyclones originate only over the seas and on reaching the land they dissipate. The extra tropical cyclone affects a much larger area as compared to the tropical cyclone. The wind velocity in a tropical cyclone is much higher and it is more destructive. The extra tropical cyclones move from west to east but tropical cyclones, move from east to west. Tropical Cyclones Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas bringing about large scale destruction caused by violent winds, very heavy rainfall and storm surges. This is one of the most devastating natural calamities. They are known as Cyclones in the Indian Ocean, Hurricanes in the Atlantic, Typhoons in the Western Pacific and South China Sea, and Willy-willies in the Western Australia. Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are: (i) Large sea surface with temperature higher than 27° C; (ii) Presence of the Coriolis force; (iii) Small variations in the vertical wind speed; (iv) A pre-existing weaklow-pressure area or low-level-cyclonic circulation; (v) Upper divergence above the sea level system. The energy that intensifies the storm, comes from the condensation process in the towering cumulonimbus clouds, surrounding the centre of the storm. With continuous supply of moisture from the sea, the storm is further strengthened. On reaching the land the moisture supply is cut off and the storm dissipates. The place where a tropical cyclone crosses the coast is called the landfall of the cyclone. The cyclones, which cross 20o N latitude generally, recurve and they are more destructive. A schematic representation of the vertical structure of a mature tropical cyclonic storm is shown in Figure 9.10. A mature tropical cyclone is characterised by the strong spirally circulating wind around the centre, called the eye. The diameter of the circulating system can vary between 150 and 250 km. The eye is a region of calm with subsiding air. Around the eye is the eye wall, where there is a strong spiralling ascent of air to greater height reaching the tropopause. The wind reaches maximum velocity in this region, reaching as high as 250 km per hour. Torrential rain occurs here. From the eye wall rain bands may radiate and trains of cumulus and cumulonimbus clouds may drift into the outer region. The diameter of the storm over the Bay of Bengal, Arabian sea and Indian ocean is between 600 - 1200 km. The system moves slowly about 300 - 500 km per day. The cyclone creates storm surges and they inundate the coastal low lands. The storm peters out on the land. Figure 9.10 : Vertical section of the tropical cyclone (after Rama Sastry) Rationalised-2023-24 84 FUNDAMENTALS OF PHYSICAL GEOGRAPHY EXERCISES 1. Multiple choice questions. (i) If the surface air pressure is 1,000 mb, the air pressure at 1 km above the surface will be: (a) 700 mb (c) 900 mb (b) 1,100 mb (d) 1,300 mb (ii) The Inter Tropical Convergence Zone normally occurs: (a) near the Equator (b) near the Tropic of Cancer (c) near the Tropic of Capricorn (d) near the Arctic Circle (iii) The direction of wind around a low pressure in northern hemisphere is: (a) clockwise (c) anti-clock wise (b) perpendicular to isobars (d) parallel to isobars (iv) Which one of the following is the source region for the formation of air masses? (a) the Equatorial forest (c) the Siberian Plain (b) the Himalayas (d) the Deccan Plateau 2. Answer the

following questions in about 30 words. (i) What is the unit used in measuring pressure? Why is the pressure measured at station level reduced to the sea level in preparation of weather maps? (ii) While the pressure gradient force is from north to south, i.e. from the subtropical high pressure to the equator in the northern hemisphere, why are the winds north easterlies in the tropics. (iii) What are the geotrophic winds? (iv) Explain the land and sea breezes. Thunderstorms and Tornadoes Other severe local storms are thunderstorms and tornadoes. They are of short duration, occurring over a small area but are violent. Thunderstorms are caused by intense convection on moist hot days. A thunderstorm is a well-grown cumulonimbus cloud producing thunder and lightening. When the clouds extend to heights where sub-zero temperature prevails, hails are formed and they come down as hailstorm. If there is insufficient moisture, a thunderstorm can generate duststorms. A thunderstorm is characterised by intense updraft of rising warm air, which causes the clouds to grow bigger and rise to greater height. This causes precipitation. Later, downdraft brings down to earth the cool air and the rain. From severe thunderstorms sometimes spiralling wind descends like a trunk of an elephant with great force, with very low pressure at the centre, causing massive destruction on its way. Such a phenomenon is called a tornado. Tornadoes generally occur in middle latitudes. The tornado over the sea is called water spouts. These violent storms are the manifestation of the atmosphere's adjustments to varying energy distribution. The potential and heat energies are converted into kinetic energy in these storms and the restless atmosphere again returns to its stable state. Rationalised-2023-24 ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS 85 3. Answer the following questions in about 150 words. (i) Discuss the factors affecting the speed and direction of wind. (ii) Draw a simplified diagram to show the general circulation of the atmosphere over the globe. What are the possible reasons for the formation of subtropical high pressure over 30o N and S latitudes? (iii) Why does tropical cyclone originate over the seas? In which part of the tropical cyclone do torrential rains and high velocity winds blow and why? Project Work (i) Collect weather information over media such as newspaper, TV and radio for understanding the weather systems. (ii) Read the section on weather in any newspaper, preferably, one having a map showing a satellite picture. Mark the area of cloudiness. Attempt to infer the atmospheric circulation from the distribution of clouds. Compare the forecast given in the newspaper with the TV coverage, if you have access to TV. Estimate, how many days in a week was the forecast were accurate. Rationalised-2023-24WATER IN THE ATMOSPHERE Y ou have already learnt that the air contains water vapour. It varies from zero to four per cent by volume of the atmosphere and plays an important role in the weather phenomena. Water is present in the atmosphere in three forms namely – gaseous, liquid and solid. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. Thus, there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation. Water vapour present in the air is known as humidity. It is expressed quantitatively in different ways. The actual amount of the water vapour present in the atmosphere is known as the absolute humidity. It is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre. The ability of the air to hold water vapour depends entirely on its temperature. The absolute humidity differs from place to place on the surface of the earth. The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the relative humidity. With the change of air temperature, the capacity to retain moisture increases or decreases and the relative humidity is also affected. It is greater over the oceans and least over the continents. The air containing moisture to its full capacity at a given temperature is said to be saturated. It means that the air at the given temperature is incapable of holding any additional amount of moisture at that stage. The temperature at which saturation occurs in a given sample of air is known as dew point. EVAPORATION AND CONDENSATION The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and

condensation respectively. Evaporation is a process by which water is transformed from liquid to gaseous state. Heat is the main cause for evaporation. The temperature at which the water starts evaporating is referred to as the latent heat of vapourisation. Increase in temperature increases water absorption and retention capacity of the given parcel of air. Similarly, if the moisture content is low, air has a potentiality of absorbing and retaining moisture. Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation. The transformation of water vapour into water is called condensation. Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form. If it directly condenses into solid form, it is known as sublimation. In free air, condensation results from cooling around very small particles termed as hygroscopic condensation nuclei. Particles of dust, smoke and salt from the ocean are particularly good nuclei because they absorb water. Condensation also takes place when the moist air comes in contact with some colder object and it may also take place when the temperature is close to the dew point. Condensation, therefore, depends upon the amount of cooling and the relative humidity of the air. Condensation is influenced by the volume of air, temperature, pressure and humidity. Condensation takes place: (i) when CHAPTER Rationalised-2023-24 WATER IN THE ATMOSPHERE 87 the temperature of the air is reduced to dew point with its volume remaining constant; (ii) when both the volume and the temperature are reduced; (iv) when moisture is added to the air through evaporation. However, the most favourable condition for condensation is the decrease in air temperature. After condensation the water vapour or the moisture in the atmosphere takes one of the following forms — dew, frost, fog and clouds. Forms of condensation can be classified on the basis of temperature and location. Condensation takes place when the dew point is lower than the freezing point as well as higher than the freezing point. Dew When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as dew. The ideal conditions for its formation are clear sky, calm air, high relative humidity, and cold and long nights. For the formation of dew, it is necessary that the dew point is above the freezing point. Frost Frost forms on cold surfaces when condensation takes place below freezing point (00C), i.e. the dew point is at or below the freezing point. The excess moisture is deposited in the form of minute ice crystals instead of water droplets. The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the air temperature must be at or below the freezing point. Fog and Mist When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. So, the fog is a cloud with its base at or very near to the ground. Because of the fog and mist, the visibility becomes poor to zero. In urban and industrial centres smoke provides plenty of nuclei which help the formation of fog and mist. Such a condition when fog is mixed with smoke, is described as smog. The only difference between the mist and fog is that mist contains more moisture than the fog. In mist each nuceli contains a thicker layer of moisture. Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface. Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents. Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles. Clouds Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable elevations. As the clouds are formed at some height over the surface of the earth, they take various shapes. According to their height, expanse, density and transparency or opaqueness clouds are grouped under four types : (i) cirrus; (ii) cumulus; (iii) stratus; (iv) nimbus. Cirrus Cirrus clouds are formed at high altitudes (8,000 - 12,000m). They are thin and detatched clouds having a feathery appearance. They are always white in colour. Cumulus Cumulus clouds look like cotton wool. They are generally formed at a height of 4,000 - 7,000 m. They exist in

patches and can be seen scattered here and there. They have a flat base. Stratus As their name implies, these are layered clouds covering large portions of the sky. These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures. Nimbus Nimbus clouds are black or dark gray. They form at middle levels or very near to the surface Rationalised-2023-24 88 FUNDAMENTALS OF PHYSICAL GEOGRAPHY of the earth. These are extremely dense and opaque to the rays of the sun. Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour. Precipitation The process of continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they fall on to the earth's surface. So after the condensation of water vapour, the release of moisture is known as precipitation. This may take place in liquid or solid form. The precipitation in the form of water is called rainfall, when the temperature is lower than the 00C, precipitation takes place in the form of fine flakes of snow and is called snowfall. Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, other forms of precipitation are sleet and hail, though the latter are limited in occurrence and are sporadic in both time and space. Sleet is frozen raindrops and refrozen melted snow-water. When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet. Raindrops, which leave the warmer air, encounter the colder air below. As a result, they solidify and reach the ground as small pellets of ice not bigger than the raindrops from which they are formed. Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called hailstones. These are formed by the rainwater passing through the colder layers. Hailstones have several concentric layers of ice one over the other. Types of Rainfall On the basis of origin, rainfall may be classified into three main types – the convectional, orographic or relief and the cyclonic or frontal. Convectional Rain The, air on being heated, becomes light and rises up in convection currents. As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. With thunder and lightening, heavy rainfall takes place but this does not last A combination of these four basic types can give rise to the following types of clouds: high clouds – cirrus, cirrostratus, cirrocumulus; middle clouds – altostratus and altocumulus; low clouds – stratocumulus and nimbostratus and clouds with extensive vertical development – cumulus and cumulonimbus. Identify these cloud types which are shown in Figure 10.1 and 10.2. Figure 10.1 Figure 10.2 Rationalised-2023-24 WATER IN THE ATMOSPHERE 89 long. Such rain is common in the summer or in the hotter part of the day. It is very common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere. Orographic Rain When the saturated air mass comes across a mountain, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed. The chief characteristic of this sort of rain is that the windward slopes receive greater rainfall. After giving rain on the windward side, when these winds reach the other slope, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry. The area situated on the leeward side, which gets less rainfall is known as the rain-shadow area. It is also known as the relief rain. Cyclonic Rain You have already read about extra tropical cyclones and cyclonic rain in Chapter 9. Please consult Chapter 9 to understand cyclonic rainfall. World Distribution of Rainfall Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons. In general, as we proceed from the equator towards the poles, rainfall goes on decreasing steadily. The coastal areas of the world receive greater amounts of rainfall than the interior of the continents. The rainfall is more over the oceans than on the landmasses of the world because of being great sources of water. Between the latitudes 350 and 400 N and S of the equator, the rain is heavier on the eastern coasts and goes on decreasing towards the west. But, between 450 and 650 N and S of equator, due to the westerlies, the rainfall is first received on the

western margins of the continents and it goes on decreasing towards the east. Wherever mountains run parallel to the coast, the rain is greater on the coastal plain, on the windward side and it decreases towards the leeward side. On the basis of the total amount of annual precipitation, major precipitation regimes of the world are identified as follows. The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone and the coastal areas of the monsoon land receive heavy rainfall of over 200 cm per annum. Interior continental areas receive moderate rainfall varying from 100 - 200 cm per annum. The coastal areas of the continents receive moderate amount of rainfall. The central parts of the tropical land and the eastern and interior parts of the temperate lands receive rainfall varying between 50 - 100 cm per annum. Areas lying in the rain shadow zone of the interior of the continents and high latitudes receive very low rainfall-less than 50 cm per annum. Seasonal distribution of rainfall provides an important aspect to judge its effectiveness. In some regions rainfall is distributed evenly throughout the year such as in the equatorial belt and in the western parts of cool temperate regions. EXERCISES 1. Multiple choice questions. (i) Which one of the following is the most important constituent of the atmosphere for human beings? (a) Water vapour (c) Dust particle (b) Nitrogen (d) Oxygen Rationalised-2023-24 90 FUNDAMENTALS OF PHYSICAL GEOGRAPHY (ii) Which one of the following process is responsible for transforming liquid into vapour? (a) Condensation (c) Evaporation (b) Transpiration (d) Precipitation (iii) The air that contains moisture to its full capacity : (a) Relative humidity (c) Absolute humidity (b) Specific humidity (d) Saturated air (iv) Which one of the following is the highest cloud in the sky? (a) Cirrus (c) Nimbus (b) Stratus (d) Cumulus 2. Answer the following questions in about 30 words. (i) Name the three types of precipitation. (ii) Explain relative humidity. (iii) Why does the amount of water vapour decreases rapidly with altitude? (iv) How are clouds formed? Classify them. 3. Answer the following questions in about 150 words. (i) Discuss the salient features of the world distribution of precipitation. (ii) What are forms of condensation? Describe the process of dew and frost formation. Project Work Browse through the newspaper from 1st June to 31st December and note the news about extreme rainfall in different parts of the country. Rationalised-2023-24WORLD CLIMATE AND CLIMATE CHANGE T he world climate can be studied by organising information and data on climate and synthesising them in smaller units for easy understanding, description and analysis. Three broad approaches have been adopted for classifying climate. They are empirical, genetic and applied. Empirical classification is based on observed data, particularly on temperature and precipitation. Genetic classification attempts to organise climates according to their causes. Applied classification is for specific purpose. KOEPPE N'S SCHEME OF CLASSIFICATION OF CLIMATE The most widely used classification of climate is the empirical climate classification scheme developed by V. Koeppen. Koeppen identified a close relationship between the distribution of vegetation and climate. He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates. It is an empirical classification based on mean annual and mean monthly temperature and precipitation data. He introduced the use of capital and small letters to designate climatic groups and types. Although developed in 1918 and modified over a period of time, Koeppen's scheme is still popular and in use. Koeppen recognised five major climatic groups, four of them are based on temperature and one on precipitation. Table 11.1 lists the climatic groups and their characteristics according to Koeppen. The capital letters : A,C, D and E delineate humid climates and B dry climates. The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics. The seasons of dryness are indicated by the small letters : f, m, w and s, where f corresponds to no dry season, Table 11.1 : Climatic Groups According to Koeppen Group Characteristics A - Tropical Average temperature of the coldest month is 18° C or higher B - Dry Climates Potential evaporation exceeds precipitation C - Warm Temperate The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but

below 18°C D - Cold Snow Forest Climates The average temperature of the coldest month is minus 3° C or below E - Cold Climates Average temperature for all months is below 10° C H - High Land Cold due to elevation CHAPTER Rationalised-2023-24 92 FUNDAMENTALS OF PHYSICAL GEOGRAPHY m - monsoon climate, w- winter dry season and s - summer dry season. The small letters a, b, c and d refer to the degree of severity of temperature. The B- Dry Climates are subdivided using the capital letters S for steppe or semi-arid and W for deserts. The climatic types are listed in Table 11.2. The distribution of climatic groups and types is shown in Table 11.1. Group A : Tropical Humid Climates Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn. The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (ITCZ) make the climate hot and humid. Annual range of temperature is very low and annual rainfall is high. The tropical group is divided into three types, namely (i) Af- Tropical wet climate; (ii) Am - Tropical monsoon climate; (iii) Aw- Tropical wet and dry climate. Tropical Wet Climate (Af) Tropical wet climate is found near the equator. The major areas are the Amazon Basin in South America, western equatorial Africa and the islands of East Indies. Significant amount of rainfall occurs in every month of the year as thunder showers in the afternoon. The temperature is uniformly high and the annual range of temperature is negligible. The maximum temperature on any day is around 30°C while the minimum temperature is around 20°C. Tropical evergreen forests with dense canopy cover and large biodiversity are found in this climate. Tropical Monsoon Climate (Am) Tropical monsoon climate (Am) is found over the Indian sub-continent, North Eastern part of South America and Northern Australia. Heavy rainfall occurs mostly in summer. Winter is dry. The detailed climatic account of this climatic type is given in the book on India: Physical Environment. Tropical Wet and Dry Climate (Aw) Tropical wet and dry climate occurs north and south of Af type climate regions. It borders with dry climate on the western part of the continent and Cf or Cw on the eastern part. Extensive Aw climate is found to the north and south of the Amazon forest in Brazil and adjoining parts Table 11.2 : Climatic Types According to Koeppen Group Type Letter Code Characteristics Tropical wet Af No dry season Tropical monsoon Am Monsoonal, short dry season Tropical wet and dry Aw Winter dry season Subtropical steppe BSh Low-latitude semi arid or dry Subtropical desert BWh Low-latitude arid or dry Mid-latitude steppe BSk Mid-latitude semi arid or dry Mid-latitude desert BWk Mid-latitude arid or dry Humid subtropical Cfa No dry season, warm summer Mediterranean Cs Dry hot summer Marine west coast Cfb No dry season, warm and cool summer Humid continental Df No dry season, severe winter Subarctic Dw Winter dry and very severe Tundra ET No true summer Polar ice cap EF Perennial ice Highland H Highland with snow cover A-Tropical Humid Climate B-Dry Climate C-Warm temperate (Midlatitude) Climates D-Cold Snowforest Climates E-Cold Climates H-Highland Rationalised-2023-24 WORLD CLIMATE AND CLIMATE CHANGE 93 of Bolivia and Paraguay in South America, Sudan and south of Central Africa. The annual rainfall in this climate is considerably less than that in Af and Am climate types and is variable also. The wet season is shorter and the dry season is longer with the drought being more severe. Temperature is high throughout the year and diurnal ranges of temperature are the greatest in the dry season. Deciduous forest and tree-shredded grasslands occur in this climate. Dry Climates : B Dry climates are characterised by very low rainfall that is not adequate for the growth of plants. These climates cover a very large area of the planet extending over large latitudes from 15° - 60° north and south of the equator. At low latitudes, from 15° - 30°, they occur in the area of subtropical high where subsidence and inversion of temperature do not produce rainfall. On the western margin of the continents, adjoining the cold current, particularly over the west coast of South America, they extend more equatorwards and occur on the coast land. In middle latitudes, from 35° - 60° north and south of equator, they are confined to the interior of continents where maritime-humid winds do not reach and to areas often surrounded by mountains. Dry climates are divided into steppe or semi-arid climate (BS) and desert climate (BW). They are further subdivided as subtropical steppe (BSh) and subtropical desert (BWh) at latitudes from 15° -

35° and mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35° - 60°. Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates Subtropical steppe (BSh) and subtropical desert (BWh) have common precipitation and temperature characteristics. Located in the transition zone between humid and dry climates, subtropical steppe receives slightly more rainfall than the desert, adequate enough for the growth of sparse grasslands. The rainfall in both the climates is highly variable. The variability in the rainfall affects the life in the steppe much more than in the desert, more often causing famine. Rain occurs in short intense thundershowers in deserts and is ineffective in building soil moisture. Fog is common in coastal deserts bordering cold currents. Maximum temperature in the summer is very high. The highest shade temperature of 58° C was recorded at Al Aziziyah, Libya on 13 September 1922. The annual and diurnal ranges of temperature are also high. Warm Temperate (Mid-Latitude) Climates-C Warm temperate (mid-latitude) climates extend from 30° - 50° of latitude mainly on the eastern and western margins of continents. These climates generally have warm summers with mild winters. They are grouped into four types: (i) Humid subtropical, i.e. dry in winter and hot in summer (Cwa); (ii) Mediterranean (Cs); (iii) Humid subtropical, i.e. no dry season and mild winter (Cfa); (iv) Marine west coast climate (Cfb). Humid Subtropical Climate (Cwa) Humid subtropical climate occurs poleward of Tropic of Cancer and Capricorn, mainly in North Indian plains and South China interior plains. The climate is similar to Aw climate except that the temperature in winter is warm. Mediterranean Climate (Cs) As the name suggests, Mediterranean climate occurs around Mediterranean sea, along the west coast of continents in subtropical latitudes between 30° - 40° latitudes e.g. — Central California, Central Chile, along the coast in south eastern and south western Australia. These areas come under the influence of sub tropical high in summer and westerly wind in winter. Hence, the climate is characterised by hot, dry summer and mild, rainy winter. Monthly average temperature in summer is around 25° C and in winter below 10°C. The annual precipitation ranges between 35 - 90 cm. Humid Subtropical (Cfa) Climate Humid subtropical climate lies on the eastern parts of the continent in subtropical latitudes. In this region the air masses are generally Rationalised-2023-24 94 FUNDAMENTALS OF PHYSICAL GEOGRAPHY unstable and cause rainfall throughout the year. They occur in eastern United States of America, southern and eastern China, southern Japan, northeastern Argentina, coastal south Africa and eastern coast of Australia. The annual averages of precipitation vary from 75-150 cm. Thunderstorms in summer and frontal precipitation in winter are common. Mean monthly temperature in summer is around 27°C, and in winter it varies from 5°-12° C. The daily range of temperature is small. Marine West Coast Climate (Cfb) Marine west coast climate is located poleward from the Mediterranean climate on the west coast of the continents. The main areas are: Northwestern Europe, west coast of North America, north of California, southern Chile, southeastern Australia and New Zealand. Due to marine influence, the temperature is moderate and in winter, it is warmer than for its latitude. The mean temperature in summer months ranges from 15°-20°C and in winter 4°-10°C. The annual and daily ranges of temperature are small. Precipitation occurs throughout the year. Precipitation varies greatly from 50-250cm. Cold Snow Forest Climates (D) Cold snow forest climates occur in the large continental area in the northern hemisphere between 40°-70° north latitudes in Europe, Asia and North America. Cold snow forest climates are divided into two types: (i) Df- cold climate with humid winter; (ii) Dw- cold climate with dry winter. The severity of winter is more pronounced in higher latitudes. Cold Climate with Humid Winters (Df) Cold climate with humid winter occurs poleward of marine west coast climate and mid latitude steppe. The winters are cold and snowy. The frost free season is short. The annual ranges of temperature are large. The weather changes are abrupt and short. Poleward, the winters are more severe. Cold Climate with Dry Winters (Dw) Cold climate with dry winter occurs mainly over Northeastern Asia. The development of pronounced winter anti cyclone and its weakening in summer sets in monsoon like reversal of wind in this region. Poleward summer temperatures are lower and winter

temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year. Precipitation occurs in summer. The annual precipitation is low from 12-15 cm. Polar Climates (E) Polar climates exist poleward beyond 70° latitude. Polar climates consist of two types: (i) Tundra (ET); (ii) Ice Cap (EF). Tundra Climate (ET) The tundra climate (ET) is so called after the types of vegetation, like low growing mosses, lichens and flowering plants. This is the region of permafrost where the sub soil is permanently frozen. The short growing season and water logging support only low growing plants. During summer, the tundra regions have very long duration of day light. Ice Cap Climate (EF) The ice cap climate (EF) occurs over interior Greenland and Antartica. Even in summer, the temperature is below freezing point. This area receives very little precipitation. The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and they break. They move as icebergs that float in the Arctic and Antarctic waters. Plateau Station , Antarctica ,79°S, portray this climate. Highland Climates (H) Highland climates are governed by topography. In high mountains, large changes in mean temperature occur over short distances. Precipitation types and intensity also vary spatially across high lands. There is vertical zonation of layering of climatic types with elevation in the mountain environment. Rationalised-2023-24 WORLD CLIMATE AND CLIMATE CHANGE 95 CLIMATE CHANGE The earlier chapters on climate summarised our understanding of climate as it prevails now. The type of climate we experience now might be prevailing over the last 10,000 years with minor and occasionally wide fluctuations. The planet earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods. The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers. The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods. The rings in the trees provide clues about wet and dry periods. Historical records describe the vagaries in climate. All these evidences indicate that change in climate is a natural and continuous process. India also witnessed alternate wet and dry periods. Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000-1,700 B.C. had higher rainfall. From about 2,000-1,700 B.C., this region was the centre of the Harappan civilisation. Dry conditions accentuated since then. In the geological past, the earth was warm some 500-300 million years ago, through the Cambrian, Ordovician and Silurian periods. During the Pleistocene epoch, glacial and inter-glacial periods occurred, the last major peak glacial period was about 18,000 years ago. The present inter-glacial period started 10,000 years ago. Climate in the recent past Variability in climate occurs all the time. The nineties decade of the last century witnessed extreme weather events. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of the Sahara desert, from 1967-1977 is one such variability. During the 1930s, severe drought occurred in southwestern Great Plains of the United States, described as the dust bowl. Historical records of crop yield or crop failures, of floods and migration of people tell about the effects of changing climate. A number of times Europe witnessed warm, wet, cold and dry periods, the significant episodes were the warm and dry conditions in the tenth and eleventh centuries, when the Vikings settled in Greenland. Europe witnessed “Little Ice Age” from 1550 to about 1850. From about 1885-1940 world temperature showed an upward trend. After 1940, the rate of increase in temperature slowed down. Causes of Climate Change The causes for climate change are many. They can be grouped into astronomical and terrestrial causes. The astronomical causes are the changes in solar output associated with sunspot activities. Sunspots are dark and cooler patches on the sun which increase and decrease in a cyclical manner. According to some meteorologists, when the number of sunspots increase, cooler and wetter weather and greater storminess occur. A decrease in sunspot numbers is associated with warm and drier conditions. Yet, these findings are not statistically significant. An another astronomical theory is Millankovitch oscillations, which infer

cycles in the variations in the earth's orbital characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. All these alter the amount of insolation received from the sun, which in turn, might have a bearing on the climate. Volcanism is considered as another cause for climate change. Volcanic eruption throws up lots of aerosols into the atmosphere. These aerosols remain in the atmosphere for a considerable period of time reducing the sun's radiation reaching the Earth's surface. After the recent Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years. The most important anthropogenic effect on the climate is the increasing trend in the concentration of greenhouse gases in the atmosphere which is likely to cause global warming. Rationalised-2023-24 96 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Global Warming Due to the presence of greenhouse gases, the atmosphere is behaving like a greenhouse. The atmosphere also transmits the incoming solar radiation but absorbs the vast majority of long wave radiation emitted upwards by the earth's surface. The gases that absorb long wave radiation are called greenhouse gases. The processes that warm the atmosphere are often collectively referred to as the greenhouse effect. The term greenhouse is derived from the analogy to a greenhouse used in cold areas for preserving heat. A greenhouse is made up of glass. The glass which is transparent to incoming short wave solar radiation is opaque to outgoing long wave radiation. The glass, therefore, allows in more radiation and prevents the long wave radiation going outside the glass house, causing the temperature inside the glasshouse structure warmer than outside. When you enter a car or a bus, during summers, where windows are closed, you feel more heat than outside. Likewise during winter the vehicles with closed doors and windows remain warmer than the temperature outside. This is another example of the greenhouse effect. Greenhouse Gases(GHGs) The primary GHGs of concern today are carbon dioxide ($CO_2$ ), Chlorofluorocarbons (CFCs), methane ($CH_4$ ), nitrous oxide ($N_2O$) and ozone ($O_3$ ). Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere. The effectiveness of any given GHG molecule will depend on the magnitude of the increase in its concentration, its life time in the atmosphere and the wavelength of radiation that it absorbs. The chlorofluorocarbons (CFCs) are highly effective. Ozone which absorbs ultra violet radiation in the stratosphere is very effective in absorbing terrestrial radiation when it is present in the lower troposphere. Another important point to be noted is that the more time the GHG molecule remains in the atmosphere, the longer it will take for earth's atmospheric system to recover from any change brought about by the latter. The largest concentration of GHGs in the atmosphere is carbon dioxide. The emission of $CO_2$ comes mainly from fossil fuel combustion (oil, gas and coal). Forests and oceans are the sinks for the carbon dioxide. Forests use $CO_2$ in their growth. So, deforestation due to changes in land use, also increases the concentration of $Co_2$ . The time taken for atmospheric $CO_2$ to adjust to changes in sources to sinks is 20-50 years. It is rising at about 0.5 per cent annually. Doubling of concentration of $CO_2$ over pre-industrial level is used as an index for estimating the changes in climate in climatic models. Chlorofluorocarbons (CFCs) are products of human activity. Ozone occurs in the stratosphere where ultra-violet rays convert oxygen into ozone. Thus, ultra violet rays do not reach the earth's surface. The CFCs which drift into the stratosphere destroy the ozone. Large depletion of ozone occurs over Antarctica. The depletion of ozone concentration in the stratosphere is called the ozone hole. This allows the ultra violet rays to pass through the troposphere. International efforts have been initiated for reducing the emission of GHGs into the atmosphere. The most important one is the Kyoto protocol proclaimed in 1997. This protocol went into effect in 2005, ratified by 141 nations. Kyoto protocol bounds the 35 industrialised countries to reduce their emissions by the year 2012 to 5 per cent less than the levels prevalent in the year 1990. The increasing trend in the concentration of GHGs in the atmosphere may, in the long run, warm up the earth. Once the global warming sets in, it will be difficult to reverse it. The effect of global warming may not be uniform everywhere. Nevertheless, the adverse effect due to global

warming will adversely affect the life supporting system. Rise in the sea level due to melting of glaciers and ice-caps and thermal expansion of the sea may inundate large parts of the coastal area and islands, leading to social problems. This is another cause for serious concern for the world Rationalised-2023-24 WORLD CLIMATE AND CLIMATE CHANGE 97 community. Efforts have already been initiated to control the emission of GHGs and to arrest the trend towards global warming. Let us hope the world community responds to this challenge and adopts a lifestyle that leaves behind a livable world for the generations to come. One of the major concerns of the world today is global warming. Let us look at how much the planet has warmed up from the temperature records. The annual average near -surface air temperature of the world is approximately 14oC. An increasing trend in temperature was discernible in the 20th century. The greatest warming of the 20th century was during the two periods, 1901-44 and 1977-99. Over each of these two periods, global temperatures rose by about 0.4oC. In between, there was a slight cooling, which was more marked in the Northern Hemisphere. The globally averaged annual mean temperature at the end of the 20th century was about 0.6oC above that recorded at the end of the 19th century. The seven warmest years during the 1856-2000 were recorded in the last decade. The year 1998 was the warmest year, probably not only for the 20th century but also for the whole millennium. Write an explanatory note on "global warming". Rationalised-2023-24 98 FUNDAMENTALS OF PHYSICAL GEOGRAPHY EXERCISES 1. Multiple choice questions. (i) Which one of the following is suitable for Koeppen's "A" type of climate? (a) High rainfall in all the months (b) Mean monthly temperature of the coldest month more than freezing point (c) Mean monthly temperature of all the months more than 18o C (d) Average temperature for all the months below 10° C (ii) Koeppen's system of classification of climates can be termed as : (a) Applied (b) Systematic (c) Genetic (d) Empirical (iii) Most of the Indian Peninsula will be grouped according to Koeppen's system under: (a) "Af" (b) "BSh" (c) "Cfb" (d) "Am" (iv) Which one of the following years is supposed to have recorded the warmest temperature the world over? (a) 1990 (b) 1998 (c) 1885 (d) 1950 (v) Which one of the following groups of four climates represents humid conditions? (a) A—B—C—E (b) A—C—D—E (c) B—C—D—E (d) A—C—D—F 2. Answer the following questions in about 30 words. (i) Which two climatic variables are used by Koeppen for classification of the climate? (ii) How is the "genetic" system of classification different from the "empirical one"? (iii) Which types of climates have very low range of temperature? (iv) What type of climatic conditions would prevail if the sun spots increase? 3. Answer the following questions in about 150 words. (i) Make a comparison of the climatic conditions between the "A" and "B" types of climate. (ii) What type of vegetation would you find in the "C" and "A" type(s) of climate? (iii) What do you understand by the term "Greenhouse Gases"? Make a list of greenhouse gases. Project Work Collect information about Kyoto declaration related to global climate changes. Rationalised-2023-24WATER (OCEANS) This unit deals with • Hydrological Cycle • Oceans — submarine relief; distribution of temperature and salinity; movements of ocean water-waves, tides and currents UNIT V Rationalised-2023-24 WATER (OCEANS) the ocean to land and land to ocean. The hydrological cycle describes the movement of water on, in, and above the earth. The water cycle has been working for billions of years and all the life on earth depends on it. Next to air, water is the most important element required for the existence of life on earth. The distribution of water on earth is quite uneven. Many locations have plenty of water while others have very limited quantity. The hydrological cycle, is the circulation of water within the earth's hydrosphere in different forms i.e. the liquid, solid and the gaseous phases. It also refers to the continuous exchange of water between the oceans, Figure 12.1 : Hydrological Cycle C an we think of life without water? It is said that the water is life. Water is an essential component of all life forms that exist over the surface of the earth. The creatures on the earth are lucky that it is a water planet, otherwise we all would have no existence. Water is a rare commodity in our solar system. There is no water on the sun or anywhere else in the solar system. The earth, fortunately has an abundant supply of water on its surface. Hence, our

planet is called the ‘Blue Planet’. HYDROLOGICAL CYCLE Water is a cyclic resource. It can be used and re-used. Water also undergoes a cycle from CHAPTER Rationalised-2023-24 WATER (OCEANS) 101 atmosphere, landsurface and subsurface and the organisms. About 71 per cent of the planetary water is found in the oceans. The remaining is held as freshwater in glaciers and icecaps, groundwater sources, lakes, soil moisture, atmosphere, streams and within life. Nearly 59 per cent of the water that falls on land returns to the atmosphere through evaporation from over the oceans as well as from other places. The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier. It is to be noted that the renewable water on the earth is constant while the demand is increasing tremendously. This leads to water crisis in different parts of the world — spatially and temporally. The pollution of river waters has further aggravated the crisis. How can you intervene in improving the water quality and augmenting the available quantity of water? RELIEF OF THE OCEAN FLOOR The oceans are confined to the great depressions of the earth’s outer layer. In this section, we shall see the nature of the ocean basins of the earth and their topography. The oceans, unlike the continents, merge so naturally into one another that it is hard to demarcate them. The geographers have divided the oceanic part of the earth into five oceans, namely the Pacific, the Atlantic, the Indian, Southern ocean and the Arctic. The various seas, bays, gulfs and other inlets are parts of these four large oceans. A major portion of the ocean floor is found between 3-6 km below the sea level. The ‘land’ under the waters of the oceans, that is, the ocean floor exhibits complex and varied features as those observed over the land (Figure 12.2). The floors of the oceans are rugged with the world’s largest mountain ranges, deepest trenches and the largest plains. These features are formed, like those of the continents, by the factors of tectonic, volcanic and depositional processes. Divisions of the Ocean Floors The ocean floors can be divided into four major divisions: (i) the Continental Shelf; (ii) the Continental Slope; (iii) the Deep Sea Plain; (iv) the Oceanic Deeps. Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc. Continental Shelf The continental shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. It is the shallowest part of the ocean showing an average gradient of 1° or even less. The shelf typically ends at a very steep slope, called the shelf break. The width of the continental shelves vary from one ocean to another. The average width of continental shelves is about 80 km. The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, the Siberian shelf in the Arctic Ocean, the largest in the world, stretches to 1,500 km in width. The depth of the shelves also varies. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m. The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents. Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels. Table 12.1 : Components and Processes of the Water Cycle Components Processes Water storage Evaporation in oceans Evapotranspiration Sublimation Water in the Condensation atmosphere Precipitation Water storage in Snowmelt runoff ice and snow to streams Surface runoff Stream flow freshwater storage infiltration Groundwater storage Groundwater discharge springs Rationalised-2023-24 102 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Continental Slope The continental slope connects the continental shelf and the ocean basins. It begins where the bottom of the continental shelf sharply drops off into a steep slope. The gradient of the slope region varies between 2-5°. The depth of the slope region varies between 200 and 3,000 m. The slope boundary indicates the end of the continents. Canyons and trenches are observed in this region. Deep Sea Plain Deep sea plains are gently sloping areas of the ocean basins. These are the flattest and smoothest regions of the world. The depths vary between 3,000 and 6,000m. These plains are covered with fine-grained sediments like clay and silt. Oceanic Deeps or Trenches These areas are the deepest parts of the oceans. The trenches are relatively steep sided, narrow basins. They are some 3-5 km

deeper than the surrounding ocean floor. They occur at the bases of continental slopes and along island arcs and are associated with active volcanoes and strong earthquakes. That is why they are very significant in the study of plate movements. As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean. Minor Relief Features Apart from the above mentioned major relief features of the ocean floor, some minor but significant features predominate in different parts of the oceans. Mid-Oceanic Ridges A mid-oceanic ridge is composed of two chains of mountains separated by a large depression. The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface. Iceland, a part of the midAtlantic Ridge, is an example. Seamount It is a mountain with pointed summits, rising from the seafloor that does not reach the surface of the ocean. Seamounts are volcanic in origin. These can be 3,000-4,500 m tall. The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example. Submarine Canyons These are deep valleys, some comparable to the Grand Canyon of the Colorado river. They are sometimes found cutting across the continental shelves and slopes, often extending Figure 12.2 : Relief features of ocean floors Rationalised-2023-24 WATER (OCEANS) 103 from the mouths of large rivers. The Hudson Canyon is the best known submarine canyon in the world. Guyots It is a flat topped seamount. They show evidences of gradual subsidence through stages to become flat topped submerged mountains. It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone. Atoll These are low islands found in the tropical oceans consisting of coral reefs surrounding a central depression. It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water. TEMPERATURE OF OCEAN WATERS This section deals with the spatial and vertical variations of temperature in various oceans. Ocean waters get heated up by the solar energy just as land. The process of heating and cooling of the oceanic water is slower than land. Factors Affecting Temperature Distribution The factors which affect the distribution of temperature of ocean water are : (i) Latitude : the temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward. (ii) Unequal distribution of land and water : the oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere. (iii) Prevailing wind : the winds blowing from the land towards the oceans drive warm surface water away form the coast resulting in the upwelling of cold water from below. It results into the longitudinal variation in the temperature. Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature. (iv) Ocean currents : warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas. Gulf stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe while the Labrador current (cold current) lowers the temperature near the north-east coast of North America. All these factors influence the temperature of the ocean currents locally. The enclosed seas in the low latitudes record relatively higher temperature than the open seas; whereas the enclosed seas in the high latitudes have lower temperature than the open seas. Horizontal and Vertical Distribution of Temperature The temperature-depth profile for the ocean water shows how the temperature decreases with the increasing depth. The profile shows a boundary region between the surface waters of the ocean and the deeper layers. The boundary usually begins around 100 - 400 m below the sea surface and extends several hundred of metres downward (Figure 12.3). This boundary region, from where there is a rapid decrease of temperature, is called the thermocline. About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0° C. The temperature structure of oceans over middle and low latitudes can be described as a three-layer system from surface to the bottom. The first layer represents the top layer of warm oceanic water and it is about 500m thick with temperatures ranging between 20° and 25° C. This layer, within the tropical region, is present throughout the year but in mid latitudes it develops only during

summer. The second layer called the thermocline layer lies below the first layer and is characterised by rapid decrease in temperature with increasing depth. The thermocline is 500 -1,000 m thick. The third layer is very cold and extends upto the deep ocean floor. In the Arctic and Rationalised-2023-24 104 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Antartic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is very slight. Here, only one layer of cold water exists, which extends from surface to deep ocean floor. The average temperature of surface water of the oceans is about 27°C and it gradually decreases from the equator towards the poles. The rate of decrease of temperature with increasing latitude is generally 0.5°C per latitude. The average temperature is around 22°C at 20° latitudes, 14° C at 40° latitudes and 0° C near poles. The oceans in the northern hemisphere record relatively higher temperature than in the southern hemisphere. The highest temperature is not recorded at the equator but slightly towards north of it. The average annual temperatures for the northern and southern hemisphere are around 19° C and 16° C respectively. This variation is due to the unequal distribution of land and water in the northern and southern hemispheres. Figure 12.4 shows the spatial pattern of surface temperature of the oceans. It is a well known fact that the maximum temperature of the oceans is always at their surfaces because they directly receive the heat from the sun and the heat is transmitted to the lower sections of the oceans through the process of convection. It results into decrease of temperature with the increasing depth, but the rate of decrease is not uniform throughout. The temperature falls very rapidly up to the depth of 200 m and thereafter, the rate of decrease of temperature is slowed down. SALINITY OF OCEAN WATERS All waters in nature, whether rain water or ocean water, contain dissolved mineral salts. Salinity is the term used to define the total content of dissolved salts in sea water (Table 12.4). It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater. It is usually expressed as parts per thousand (o/oo ) or ppt. Salinity is an important property of sea water. Salinity of 24.7 o/oo has been considered as the upper limit to demarcate ‘brackish water’. Factors affecting ocean salinity are mentioned below: (i) The salinity of water in the surface layer of oceans depend mainly on evaporation and precipitation. (ii) Surface salinity is greatly influenced in coastal regions by the fresh water flow from rivers, and in polar regions by the processes of freezing and thawing of ice. (iii) Wind, also influences salinity of an area by transferring water to other areas. (iv) The ocean currents contribute to the salinity variations. Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of water in an area. Highest salinity in water bodies Lake Van in Turkey (330 o/oo ), Dead Sea (238 o/oo ), Great Salt Lake (220 o/oo ) Figure 12.3 : Thermocline Rationalised-2023-24 WATER (OCEANS) 105 The North Sea, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift. Baltic Sea records low salinity due to influx of river waters in large quantity. The Mediterranean Sea records higher salinity due to high evaporation. Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers. See the atlas to find out the rivers joining Black Sea. The average salinity of the Indian Ocean is 35 o/oo. The low salinity trend is observed in the Bay of Bengal due to influx of river water. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water. Figure 12.5 shows the salinity of the World’s oceans. Vertical Distribution of Salinity Salinity changes with depth, but the way it changes depends upon the location of the Figure 12.4 : Spatial pattern of surface temperature (°C) of the oceans HORIZONTAL DISTRIBUTION OF SALINITY The salinity for normal open ocean ranges between 33o/oo and 37 o/oo . In the land locked Red Sea, it is as high as 41o/oo , while in the estuaries and the Arctic, the salinity fluctuates from 0 - 35 o/oo , seasonally. In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70 o/oo . The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent. Salinity decreases from 35 o/oo - 31 o/oo on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region. In the same way, after 15° - 20° south, it

decreases to 33 o/oo . The average salinity of the Atlantic Ocean is around 36 o/oo. The highest salinity is recorded between 15° and 20° latitudes. Maximum salinity (37 o/oo ) is observed between 20° N and 30° N and 20° W - 60° W. It gradually decreases towards the north. Rationalised-2023-24 106 FUNDAMENTALS OF PHYSICAL GEOGRAPHY sea. Salinity at the surface increases by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers. Salinity at depth is very much fixed, because there is no way that water is 'lost', or the salt is 'added.' There is a marked difference in the salinity between the surface zones and the deep zones of the oceans. The lower salinity water rests above Figure12.5 : Surface salinity of the World's Oceans the higher salinity dense water. Salinity, generally, increases with depth and there is a distinct zone called the halocline, where salinity increases sharply. Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to stratification by salinity. EXERCISES 1. Multiple choice questions. (i) Identify the element which is not a part of the hydrological cycle (a) Evaporation (c) Precipitation (b) Hydration (d) Condensation (ii) The average depth of continental slope varies between (a) 2–20m (c) 20–200m (b) 200–2,000m (d) 2,000–20,000m 120º 60º 60º 120º 120º 60º 60º 120º Rationalised-2023-24 WATER (OCEANS) 107 (iii) Which one of the following is not a minor relief feature in the oceans: (a) Seamount (c) Oceanic Deep (b) Atoll (d) Guyot (iv) Salinity is expressed as the amount of salt in grams dissolved in sea water per (a) 10 gm (c) 100 gm (b) 1,000 gm (d) 10,000 gm (v) Which one of the following is the smallest ocean: (a) Indian Ocean (c) Atlantic Ocean (b) Arctic Ocean (d) Pacific Ocean 2. Answer the following questions in about 30 words. (i) Why do we call the earth a Blue Planet? (ii) What is a continental margin? (iii) List out the deepest trenches of various oceans. (iv) What is a thermocline? (v) When you move into the ocean what thermal layers would you encounter? Why the temperature varies with depth? (vi) What is salinity of sea water? 3. Answer the following questions in about 150 words. (i) How are various elements of the hydrological cycle interrelated? (ii) Examine the factors that influence the temperature distribution of the oceans. Project Work (i) Consult the atlas and show ocean floor relief on the outline of the world map. (ii) Identify the areas of mid oceanic ridges from the Indian Ocean. Rationalised-2023-24MOVEMENTS OF OCEAN WATER T he ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water. The horizontal and vertical motions are common in ocean water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides. Ocean currents are the continuous flow of huge amount of water in a definite direction while the waves are the horizontal motion of water. Water moves ahead from one place to another through ocean currents while the water in the waves does not move, but the wave trains move ahead. The vertical motion refers to the rise and fall of water in the oceans and seas. Due to attraction of the sun and the moon, the ocean water is raised up and falls down twice a day. The upwelling of cold water from subsurface and the sinking of surface water are also forms of vertical motion of ocean water. WAVES Waves are actually the energy, not the water as such, which moves across the ocean surface. Water particles only travel in a small circle as a wave passes. Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines. The motion of the surface water seldom affects the stagnant deep bottom water of the oceans. As a wave approaches the beach, it slows down. This is due to the friction occurring between the dynamic water and the sea floor. And, when the depth of water is less than half the wavelength of the wave, the wave breaks. The largest waves are found in the open oceans. Waves continue to grow larger as they move and absorb energy from the wind. Most of the waves are caused by the wind driving against water. When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves. Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf. A wave's size and shape reveal its origin. Steep waves are

fairly young ones and are probably formed by local wind. Slow and steady waves originate from far away places, possibly from another hemisphere. The maximum wave height is determined by the strength of the wind, i.e. how long it blows and the area over which it blows in a single direction. Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the Figure13.1 : Motion of waves and water molecules CHAPTER Rationalised-2023-24 MOVEMENTS OF OCEAN WATER 109 wave moves to a new position (Figure 13.1). The actual motion of the water beneath the waves is circular. It indicates that things are carried up and forward as the wave approaches, and down and back as it passes. Characteristics of Waves Wave crest and trough : The highest and lowest points of a wave are called the crest and trough respectively. Wave height : It is the vertical distance from the bottom of a trough to the top of a crest of a wave. Wave amplitude : It is one-half of the wave height. Wave period : It is merely the time interval between two successive wave crests or troughs as they pass a fixed point. Wavelength : It is the horizontal distance between two successive crests. Wave speed : It is the rate at which the wave moves through the water, and is measured in knots. Wave frequency : It is the number of waves passing a given point during a onesecond time interval. TIDES The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide. Movement of water caused by meteorological effects (winds and atmospheric pressure changes) are called surges. Surges are not regular like tides. The study of tides is very complex, spatially and temporally, as it has great variations in frequency, magnitude and height. The moon's gravitational pull to a great extent and to a lesser extent the sun's gravitational pull, are the major causes for the occurrence of tides. Another factor is centrifugal force, which is the force that acts to counter balance the gravity. Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side (Figure 13.2). The 'tide-generating' force is the difference between these two forces; i.e. the gravitational attraction of the moon and the centrifugal force. On the surface of the earth, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon. On the opposite side of the earth, the attractive force is less, as it is farther away from the moon, the centrifugal force is dominant. Hence, there is a net force away from the moon. It creates the second bulge away from the moon. On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges. Figure13.2 : Relation between gravitational forces and tides The tidal bulges on wide continental shelves, have greater height. When tidal bulges hit the mid-oceanic islands they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channelled between islands or into bays and estuaries they are called tidal currents. Rationalised-2023-24 110 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Tides of Bay of Fundy, Canada The highest tides in the world occur in the Bay of Fundy in Nova Scotia, Canada. The tidal bulge is 15 - 16 m. Because there are two high tides and two low tides every day (roughly a 24 hour period); then a tide must come in within about a six hour period. As a rough estimate, the tide rises about 240 cm an hour (1,440 cm divided by 6 hours). If you have walked down a beach with a steep cliff alongside (which is common there), make sure you watch the tides. If you walk for about an hour and then notice that the tide is coming in, the water will be over your head before you get back to where you started! Types of Tides Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height. Tides based on Frequency Semi-diurnal tide : The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides

are approximately of the same height. Diurnal tide : There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height. Mixed tide : Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean. Tides based on the Sun, Moon and the Earth Positions The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category. Spring tides : The position of both the sun and the moon in relation to the earth has direct bearing on tide height. When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. These are called spring tides and they occur twice a month, one on full moon period and another during new moon period. Neap tides : Normally, there is a seven day interval between the spring tides and neap tides. At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another. The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull. Once in a month, when the moon's orbit is closest to the earth (perigee), unusually high and low tides occur. During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth (apogee), the moon's gravitational force is limited and the tidal ranges are less than their average heights. When the earth is closest to the sun (perihelion), around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides. When the earth is farthest from the sun (aphelion), around 4th July each year, tidal ranges are much less than average. The time between the high tide and low tide, when the water level is falling, is called the ebb. The time between the low tide and high tide, when the tide is rising, is called the flow or flood. Importance of Tides Since tides are caused by the earth-moon-sun positions which are known accurately, the tides can be predicted well in advance. This helps the navigators and fishermen plan their activities. Tidal flows are of great importance in navigation. Tidal heights are very important, especially harbours near rivers and within estuaries having shallow 'bars' at the entrance, which prevent ships and boats from entering into the harbour. Tides are also helpful in Rationalised-2023-24 MOVEMENTS OF OCEAN WATER 111 desilting the sediments and in removing polluted water from river estuaries. Tides are used to generate electrical power (in Canada, France, Russia, and China). A 3 MW tidal power project at Durgaduani in Sunderbans of West Bengal is under way. OCEAN CURRENTS Ocean currents are like river flow in oceans. They represent a regular volume of water in a definite path and direction. Ocean currents are influenced by two types of forces namely : (i) primary forces that initiate the movement of water; (ii) secondary forces that influence the currents to flow. The primary forces that influence the currents are: (i) heating by solar energy; (ii) wind; (iii) gravity; (iv) coriolis force. Heating by solar energy causes the water to expand. That is why, near the equator the ocean water is about 8 cm higher in level than in the middle latitudes. This causes a very slight gradient and water tends to flow down the slope. Wind blowing on the surface of the ocean pushes the water to move. Friction between the wind and the water surface affects the movement of the water body in its course. Gravity tends to pull the water down the pile and create gradient variation. The Coriolis force intervenes and causes the water to move to the right in the northern hemisphere and to the left in the southern hemisphere. These large accumulations of water and the flow around them are called Gyres. These produce large circular currents in all the ocean basins. Differences in water density affect vertical mobility of ocean currents. Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Denser water tends to sink, while relatively lighter water tends to rise. Cold-water ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator. Warm-water currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water. Types of Ocean Currents The ocean currents may be classified based on their depth as surface currents and deep water currents : (i) surface currents constitute about 10 per cent

of all the water in the ocean, these waters are the upper 400 m of the ocean; (ii) deep water currents make up the other 90 per cent of the ocean water. These waters move around the ocean basins due to variations in the density and gravity. Deep waters sink into the deep ocean basins at high latitudes, where the temperatures are cold enough to cause the density to increase. Ocean currents can also be classified based on temperature : as cold currents and warm currents: (i) cold currents bring cold water into warm water areas. These currents are usually found on the west coast of the continents in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere; (ii) warm currents bring warm water into cold water areas and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere they are found on the west coasts of continents in high latitudes. Major Ocean Currents Major ocean currents are greatly influenced by the stresses exerted by the prevailing winds and coriolis force. The oceanic circulation pattern roughly corresponds to the earth's atmospheric circulation pattern. The air circulation over the oceans in the middle latitudes is mainly anticyclonic (more pronounced in the southern hemisphere than in the northern hemisphere). The oceanic circulation pattern also corresponds with the same. At higher latitudes, Characteristics of Ocean Currents Currents are referred to by their "drift". Usually, the currents are strongest near the surface and may attain speeds over five knots. At depths, currents are generally slow with speeds less than 0.5 knots. We refer to the speed of a current as its "drift." Drift is measured in terms of knots. The strength of a current refers to the speed of the current. A fast current is considered strong. A current is usually strongest at the surface and decreases in strength (speed) with depth. Most currents have speeds less than or equal to 5 knots. Rationalised-2023-24 112 FUNDAMENTALS OF PHYSICAL GEOGRAPHY where the wind flow is mostly cyclonic, the oceanic circulation follows this pattern. In regions of pronounced monsoonal flow, the monsoon winds influence the current movements. Due to the coriolis force, the warm currents from low latitudes tend to move to the right in the northern hemisphere and to their left in the southern hemisphere. The oceanic circulation transports heat from one latitude belt to another in a manner similar to the heat transported by the general circulation of the atmosphere. The cold waters of the Arctic and Antarctic circles move towards warmer water in tropical and equatorial regions, while the warm waters of the lower latitudes move polewards. The major currents in the different oceans are shown in Figure13.3. Prepare a list of currents which are found in Pacific, Atlantic and Indian Oceans. How is the movement of currents influenced by prevailing winds? Give some examples from Figure13.3. Effects of Ocean Currents Ocean currents have a number of direct and indirect influences on human activities. West coasts of the continents in tropical and subtropical latitudes (except close to the equator) are bordered by cool waters. Their average temperatures are relatively low with a narrow diurnal and annual ranges. There is fog, but generally the areas are arid. West coasts of the continents in the middle and higher latitudes are bordered by warm waters which cause a distinct marine climate. They are characterised by cool summers and relatively mild winters with a narrow annual range of temperatures. Warm currents flow parallel to the east coasts of the continents in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones. The mixing of warm and cold currents help to replenish the oxygen and favour the growth of planktons, the primary food for fish population. The best fishing grounds of the world exist mainly in these mixing zones. Fig.13.3 : Major currents in the Pacific, Atlantic and Indian oceans Rationalised-2023-24 MOVEMENTS OF OCEAN WATER 113 EXERCISES 1. Multiple choice questions. (i) Upward and downward movement of ocean water is known as the : (a) tide (c) wave (b) current (d) none of the above (ii) Spring tides are caused : (a) As result of the moon and the sun pulling the earth gravitationally in the same direction. (b) As result of the moon and the sun pulling the earth gravitationally in the opposite direction. (c) Indention in the coast line. (d) None of the above. (iii) The distance between the earth and the moon is minimum

when the moon is in : (a) Aphelion (c) Perihelion (b) Perigee (d) Apogee (iv) The earth reaches its perihelion in: (a) October (c) July (b) September (d) January 2. Answer the following questions in about 30 words. (i) What are waves? (ii) Where do waves in the ocean get their energy from? (iii) What are tides? (iv) How are tides caused? (v) How are tides related to navigation? 3. Answer the following questions in about 150 words. (i) How do currents affect the temperature? How does it affect the temperature of coastal areas in the N. W. Europe? (ii) What are the causes of currents? Project Work (i) Visit a lake or a pond and observe the movement of waves. Throw a stone and notice how waves are generated. (ii) Take a globe and a map showing the currents of the oceans. Discuss why certain currents are warm or cold and why they deflect in certain places and examine the reasons. Rationalised-2023-24114 FUNDAMENTALS OF PHYSICAL GEOGRAPHY LIFE ON THE EARTH This unit deals with • Biosphere — biodiversity and conservation UNIT VI Rationalised-2023-24 BIODIVERSITY AND CONSERVATION Y ou have already learnt about the geomorphic processes particularly weathering and depth of weathering mantle in different climatic zones. See the Figure 5.2 in Chapter 5 in order to recapitulate. You should know that this weathering mantle is the basis for the diversity of vegetation and hence, the biodiversity. The basic cause for such weathering variations and resultant biodiversity is the input of solar energy and water. No wonder that the areas that are rich in these inputs are the areas of wide spectrum of biodiversity. Biodiversity as we have today is the result of 2.5-3.5 billion years of evolution. Before the advent of humans, our earth supported more biodiversity than in any other period. Since, the emergence of humans, however, biodiversity has begun a rapid decline, with one species after another bearing the brunt of extinction due to overuse. The number of species globally vary from 2 million to 100 million, with 10 million being the best estimate. New species are regularly discovered most of which are yet to be classified (an estimate states that about 40 per cent of fresh water fishes from South America are not classified yet). Tropical forests are very rich in bio-diversity. Biodiversity is a system in constant evolution, from a view point of species, as well as from view point of an individual organism. The average half-life of a species is estimated at between one and four million years, and 99 per cent of the species that have ever lived on the earth are today extinct. Biodiversity is not found evenly on the earth. It is consistently richer in the tropics. As one approaches the polar regions, one finds larger and larger populations of fewer and fewer species. Biodiversity itself is a combination of two words, Bio (life) and diversity (variety). In simple terms, biodiversity is the number and variety of organisms found within a specified geographic region. It refers to the varieties of plants, animals and micro-organisms, the genes they contain and the ecosystems they form. It relates to the variability among living organisms on the earth, including the variability within and between the species and that within and between the ecosystems. Biodiversity is our living wealth. It is a result of hundreds of millions of years of evolutionary history. Biodiversity can be discussed at three levels : (i) Genetic diversity; (ii) Species diversity; (iii) Ecosystem diversity. Genetic Diversity Genes are the basic building blocks of various life forms. Genetic biodiversity refers to the variation of genes within species. Groups of individual organisms having certain similarities in their physical characteristics are called species. Human beings genetically belong to the homo sapiens group and also differ in their characteristics such as height, colour, physical appearance, etc., considerably. This is due to genetic diversity. This genetic diversity is essential for a healthy breeding of population of species. CHAPTER Rationalised-2023-24 116 FUNDAMENTALS OF PHYSICAL GEOGRAPHY Species Diversity This refers to the variety of species. It relates to the number of species in a defined area. The diversity of species can be measured through its richness, abundance and types. Some areas are more rich in species than others. Areas rich in species diversity are called hotspots of diversity (Figure 14.5). Ecosystem Diversity You have studied about the ecosystem in the earlier chapter. The broad differences between ecosystem types and the diversity of habitats and ecological processes occurring within each ecosystem type constitute the ecosystem diversity. The ‘boundaries’ of communities

(associations of species) and ecosystems are not very rigidly defined. Thus, the demarcation of ecosystem boundaries is difficult and complex. ecosystem evolves and sustains without any reason. That means, every organism, besides extracting its needs, also contributes something of useful to other organisms. Can you think of the way we, humans contribute to the sustenance of ecosystems. Species capture and store energy, produce and decompose organic materials, help to cycle water and nutrients throughout the ecosystem, fix atmospheric gases and help regulate the climate. These functions are important for ecosystem function and human survival. The more diverse an ecosystem, better are the chances for the species to survive through adversities and attacks, and consequently, is more productive. Hence, the loss of species would decrease the ability of the system to maintain itself. Just like a species with a high genetic diversity, an ecosystem with high biodiversity may have a greater chance of adapting to environmental change. In other words, the more the variety of species in an ecosystem, the more stable the ecosystem is likely to be. Economic Role of Biodiversity For all humans, biodiversity is an important resource in their day-to-day life. One important part of biodiversity is 'crop diversity', which is also called agro-biodiversity. Biodiversity is seen as a reservoir of resources to be drawn upon for the manufacture of food, pharmaceutical, and cosmetic products. This concept of biological resources is responsible for the deterioration of biodiversity. At the same time, it is also the origin of new conflicts dealing with rules of division and appropriation of natural resources. Some of the important economic commodities that biodiversity supplies to humankind are: food crops, livestock, forests, fish, medicinal resources, etc. Scientific Role of Biodiversity Biodiversity is important because each species can give us some clue as to how life evolved and will continue to evolve. Biodiversity also helps in understanding how life functions and the role of each species in sustaining Importance of Biodiversity Biodiversity has contributed in many ways to the development of human culture and, in turn, human communities have played a major role in shaping the diversity of nature at the genetic, species and ecological levels. Biodiversity plays the following roles: ecological, economic and scientific. Ecological Role of Biodiversity Species of many kinds perform some function or the other in an ecosystem. Nothing in an Figure 14.1 : Grasslands and sholas in Indira Gandhi National Park, Annamalai, Western Ghats — an example of ecosystem diversity Rationalised-2023-24 BIODIVERSITY AND CONSERVATION 117 ecosystems of which we are also a species. This fact must be drawn upon every one of us so that we live and let other species also live their lives. It is our ethical responsibility to consider that each and every species along with us have an intrinsic right to exist. Hence, it is morally wrong to voluntarily cause the extinction of any species. The level of biodiversity is a good indicator of the state of our relationships with other living species. In fact, the concept of biodiversity is an integral part of many human cultures. LOSS OF BIODIVERSITY Since the last few decades, growth in human population has increased the rate of consumption of natural resources. It has accelerated the loss of species and habitation in different parts of the world. Tropical regions which occupy only about one-fourth of the total area of the world, contain about threefourth of the world human population. Overexploitation of resources and deforestation have become rampant to fulfil the needs of large population. As these tropical rain forests contain 50 per cent of the species on the earth, destruction of natural habitats have proved disastrous for the entire biosphere. Natural calamities such as earthquakes, floods, volcanic eruptions, forest fires, droughts, etc. cause damage to the flora and fauna of the earth, bringing change the biodiversity of respective affected regions. Pesticides and other pollutants such as hydrocarbons and toxic heavy metals destroy the weak and sensitive species. Species which are not the natural inhabitants of the local habitat but are introduced into the system, are called exotic species. There are many examples when a natural biotic community of the ecosystem suffered extensive damage because of the introduction of exotic species. During the last few decades, some animals like tigers, elephants, rhinoceros, crocodiles, minks and birds were hunted mercilessly by poachers for their horn, tusks, hides, etc. It has resulted in the rendering of certain types of

organisms as endangered category. The International Union of Conservation of Nature and Natural Resources (IUCN) has classified the threatened species of plants and animals into three categories for the purpose of their conservation. Endangered Species It includes those species which are in danger of extinction. The IUCN publishes information about endangered species world-wide as the Red List of threatened species. Vulnerable Species This includes the species which are likely to be in danger of extinction in near future if the factors threatening to their extinction continue. Survival of these species is not assured as their population has reduced greatly. Rare Species Population of these species is very small in the world; they are confined to limited areas or thinly scattered over a wider area. CONSERVATION OF BIODIVERSITY Biodiversity is important for human existence. All forms of life are so closely interlinked that disturbance in one gives rise to imbalance in the others. If species of plants and animals become endangered, they cause degradation in the environment, which may threaten human being's own existence. Figure 14.2 : Red Panda — an endangered species Rationalised-2023-24 118 FUNDAMENTALS OF PHYSICAL GEOGRAPHY (iv) Each country should identify habitats of wild relatives and ensure their protection. (v) Habitats where species feed, breed, rest and nurse their young should be safeguarded and protected. (vi) International trade in wild plants and animals be regulated. To protect, preserve and propagate the variety of species within natural boundaries, the Government of India passed the Wild Life (Protection) Act, 1972, under which national parks and sanctuaries were established and biosphere reserves declared. Details of these biosphere reserves are given in the book India: Physical Environment (NCERT, 2006). There are some countries which are situated in the tropical region; they possess a large number of the world's species diversity. They are called mega diversity centres. There are 12 such countries, namely Mexico, Columbia, Ecuador, Peru, Brazil, Democratic Republic of Congo, Madagascar, China, India, Malaysia, Indonesia and Australia in which these centres are located. In order to concentrate resources on those areas that are most vulnerable, the International Union for the Conservation of Nature and Natural Resources (IUCN) has identified certain areas as biodiversity hotspots (Figure 14.1). Hotspots are defined according to their vegetation. Plants are important because these determine the primary productivity of an ecosystem. Most, but not all, of the hotspots rely on species-rich ecosystems for food, firewood, cropland, and income from timber. In Madagascar, for example, about 85 per cent of the plants and animals are found nowhere else in the world, Other hotspots in wealthy countries are facing different types of pressures. The islands of Hawaii have many unique plants and animals that are threatened by introduced species and land development. There is an urgent need to educate people to adopt environment-friendly practices and reorient their activities in such a way that our development is harmonious with other life forms and is sustainable. There is an increasing consciousness of the fact that such conservation with sustainable use is possible only with the involvement and cooperation of local communities and individuals. For this, the development of institutional structures at local levels is necessary. The critical problem is not merely the conservation of species nor the habitat but the continuation of process of conservation. The Government of India along with 155 other nations have signed the Convention of Biodiversity at the Earth Summit held at Rio de Janeiro, Brazil in June 1992. The world conservation strategy has suggested the following steps for biodiversity conservation: (i) Efforts should be made to preserve the species that are endangered. (ii) Prevention of extinction requires proper planning and management. (iii) Varieties of food crops, forage plants, timber trees, livestock, animals and their wild relatives should be preserved; Figure 14.3 : Humbodtia decurrens Bedd — highly rare endemic tree of Southern Western Ghats (India) Rationalised-2023-24 BIODIVERSITY AND CONSERVATION 119 Figure 14.4 : Some ecological 'hotspots' in the world EXERCISES 1. Multiple choice questions. (i) Conservation of biodiversity is important for : (a) Animals (c) Plants (b) Animals and plants (d) All organisms (ii) Threatened species are those which : (a) threaten others (b) Lion and tiger (c) are abundant in number (d) are suffering from the danger of extinction (iii) National parks and sanctuaries are established for the purpose of :

(a) Recreation (c) Pets (b) Hunting (d) Conservation Rationalised-2023-24 120 FUNDAMENTALS OF PHYSICAL GEOGRAPHY (iv) Biodiversity is richer in : (a) Tropical Regions (c) Temperate Regions (b) Polar Regions (d) Oceans (v) In which one of the following countries, the 'Earth Summit' was held? (a) the UK (c) Brazil (b) Mexico (d) China 2. Answer the following questions in about 30 words. (i) What is biodiversity? (ii) What are the different levels of biodiversity? (iii) What do you understand by 'hotspots'? (iv) Discuss briefly the importance of animals to human kind. (v) What do you understand by 'exotic species'? 3. Answer the following questions in about 150 words. (i) What are the roles played by biodiversity in the shaping of nature? (ii) What are the major factors that are responsible for the loss of biodiversity? What steps are needed to prevent them? Project Work Collect the names of national parks, sanctuaries and biosphere reserves of the state where your school is located and show their location on the map of India. Rationalised-2023-24