Order^{and} Disorder

Science Essentials for
the Non-Scientist

This page is intentionally left blank

Order^{and} Disorder

Science Essentials for
the Non-Scientist

Myron Kaufman

Emory University, USA

Imperial College Press

Published by

Imperial College Press
57 Shelton Street
Covent Garden
London WC2H 9HE

Distributed by

World Scientific Publishing Co. Pte. Ltd.

5 Toh Tuck Link, Singapore 596224

USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601

UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

ORDER AND DISORDER

Science Essentials for the Non-Scientist

Copyright © 2011 by Imperial College Press

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN-13 978-1-84816-574-8

ISBN-10 1-84816-574-9

Typeset by Stallion Press

Email: enquiries@stallionpress.com

Printed in Singapore.

Contents

<i>Preface</i>	vii
1 The Nature of Science	1
2 Order	15
3 Particles	31
4 Forces and Motion	45
5 Waves	61
6 Energy	75
7 Particle-Waves	93
8 The New Physics	113
9 Atoms	127
10 The Elements	139
11 Compounds	157
12 Organic Compounds	175
13 Entropy	193
14 Equilibrium and Steady State	207
15 Introduction to Life	221

16	The Components of Life	241
17	Molecules of Life	257
18	Information Storage and Transmission in Life	275
19	Beyond the Cell	293
20	The Nervous System	317
21	The Earth	333
22	Ecology and Evolution	355
23	Astronomy	369
	<i>Appendix</i>	395
	<i>Glossary</i>	397
	<i>Credits</i>	433
	<i>Index</i>	437

Preface

As C. P. Snow, the British physicist and novelist, noted a half-century ago, intellectual society is divided into two cultures, literary and scientific, and these groups are each incapable of appreciating the other, much to the detriment of society and individuals. With the advancement of science, Snow's observation is probably even more valid today. While scientists, if they are so inclined, can probably remedy some of their literary shortcomings in their post-university life, it is challenging for literary intellectuals to make much progress learning science on their own.

Science has become increasingly important in the lives of all citizens. Every day we have to make medical, investment and political decisions for which a modicum of scientific knowledge is required. Science is too important to be left to the scientists, doctors and stockbrokers. In addition, our lives are filled with technological devices, whose use is facilitated by just a little scientific understanding. And wouldn't it be great if we could understand the exciting scientific advances reported in the media? Scientific ideas have also made their way into our vocabulary. When terms such as symmetry, entropy, gender, genes, mind or sustainability, are used in conversation, it would be helpful to know just what we and others are talking about.

From my experience as a faculty member of Emory University and from perusing the catalogs of other institutions of higher learning, I doubt that American universities are preparing their non-science students to function in our scientific-oriented society after they graduate. This shortcoming affects even the most elite of U. S. educational institutions, as

indicated by 22 of 25 graduating Harvard students being unable to correctly answer the question “Why is it warm in summer and cold in winter?” Meanwhile the American public remains exceedingly open to mystical ideas. Polls have reported that a large fraction of Americans believe in ghosts and astrology. Can our society be at once the most technically advanced and the least scientifically knowledgeable among the developed nations, and continue to prosper? This doesn’t seem possible.

I believe a major cause for the scientific illiteracy of non-science graduates of major universities is the lack of good courses designed for them in this area. Offerings are often “watered-down” versions of regular science courses or special topic courses taught at a superficial level. One reason for this is that science is built on a pyramidal structure. To understand biology, you need chemistry; to understand chemistry, you need physics; underlying the entire structure is mathematics.

Over a decade ago, I started to teach a course at Emory University that I hoped would circumvent this difficulty. By teaching physics in an intuitive, non-mathematical way, I hoped to cover sufficient background, so students could understand the basic ideas of chemistry and then go on and apply their physics and chemistry to biology, geology and astronomy. Since I couldn’t find an appropriate textbook for the course, I began by providing the students with handouts on each of the topics. Those handouts have provided the foundation for this book. Since the ultimate goal of science is to understand the universe, I decided to tie the topics together with the theme of order and disorder – explaining the tendencies of Nature to move in each of these directions. Realizing that the vocabulary of science is quite extensive, I have included a glossary at the end of the book.

I must admit that I also had another goal in developing my course. As a practicing scientist for many years, I began to be aware of how limited my own scientific training had been. Frustrated at not being able to follow seminars whose titles interested me, it was exciting to go back and learn the basics of the various sciences. I suspect many other scientists have similar feelings, but are not at a stage of their careers where they can invest the time to do this. Perhaps this book would also be of some interest to them.

I am indebted to faculty members at Emory University who have helped me out by leading classes in my course, while I was learning their subjects. Edmund Day and Richard Williamon of Physics, Stephan Lutz of Chemistry (with a biochemistry specialty), Chris Beck and Walter

Escobar of Biology, Darryl Neill of Psychology, Paul Lennard of Neuroscience and William Size and Anthony Martin of Environmental Studies contributed over the years. In addition Amy Benson Brown of Emory's Manuscript Development Program read an early version of the book and provided very useful feedback. I always solicited comments from my class on the handouts, and one year even offered extra credit for these. Many of the student comments were very helpful.

Most of all, I would like to thank my wife, June, who read all the chapters, some more than once. In addition to her fine editorial eye, she continually encouraged me to make the book simpler and more relevant. I tried to take her advice, but for some of the topics I just didn't feel it was possible. Where the book is difficult, obscure or boring, the fault is all mine.