Understanding Human Metabolism

Does eating more carbohydrates, or fats, cause one to put on more weight? Are ketone bodies toxins or vital products that keep us alive during starvation? Does the concept of ‘fat-burning exercise’ hold true? In this game-changing book, Keith Frayn, an international expert in human metabolism and nutrition, dispels common misconceptions about human metabolism, explaining in everyday language the important metabolic processes that underlie all aspects of our daily lives. Illustrated throughout with clear diagrams of metabolic processes, Frayn describes the communication systems that enable our different organs and tissues to cooperate, for instance in providing fuel to our muscles when we exercise, and in preserving our tissues during fasting. He explores the impressive adaptability of human metabolism and discusses the metabolic disorders that can arise when metabolism ‘goes wrong.’ For anyone sceptical of information about diet and lifestyle, this concise book guides the reader through what metabolism really involves.

Keith Frayn is Emeritus Professor of Human Metabolism at the University of Oxford, UK. In a long and varied career studying human metabolism and nutrition, he has worked in various settings, from diabetes clinics to Accident and Emergency departments and Intensive Care wards. His work has been widely recognised with awards including the first Blaxter Medal of the Nutrition Society, the David Cuthbertson Lecture at the European Society of Parenteral and Enteral Nutrition, and Honorary Fellowship of the Nutrition Society.
The *Understanding Life* series is for anyone wanting an engaging and concise way into a key biological topic. Offering a multidisciplinary perspective, these accessible guides address common misconceptions and misunderstandings in a thoughtful way to help stimulate debate and encourage a more in-depth understanding. Written by leading thinkers in each field, these books are for anyone wanting an expert overview that will enable clearer thinking on each topic.

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Understanding Human Metabolism

KEITH N. FRAYN
Emeritus Professor of Human Metabolism, University of Oxford
Are you interested in your health and want to understand how your body functions? Do you want to learn the science behind how food and exercise interact and how together they can both foster wellbeing or lead to poor health and disease? This, and all you need to know about the key role of human metabolism for health and disease, is what Understanding Human Metabolism gives you. The author, Professor Keith Frayn, is probably the best teacher of human metabolism and nutrition of our times and has published several superb books on the topic for students of medicine and nutrition. This time, I would like to congratulate anyone without medical training but with an interest in human metabolism – this is the book for you.

Olle Ljungqvist, Professor of Surgery, Örebro University and Affiliated Professor of Surgery, Nutrition and Metabolism, Karolinska Institute, Sweden

Insightful, objective, easy reading. Nutritional biochemistry and metabolism in the right measure.

Teresa H M da Costa, Professor, Department of Nutrition, University of Brasília, Brazil

Everyone has a metabolism, and most people have a folk understanding of it. This very clear account of this actually complex subject brings science to bear on such understandings. Reading it will help you understand yourself better.

Stanley Ulijaszek, Professor of Human Ecology, University of Oxford, UK
Contents

Foreword                                      page xiii
Preface                                        xv
Acknowledgements                                xix

1 What Is Metabolism?                              1
   Metabolism Is a Very Big Subject               1
   Metabolism Developed Very Early in Evolution   2
   Human Metabolism Must Depend upon a Flow of Information  3
   How Did Our Present Views of Metabolism Evolve?  5
   Human Metabolism in a Wider Context            11
   What Is Metabolism? Conclusion                 12

2 Metabolic Fuels                                 13
   Humans, like the Cordless Vacuum Cleaner, Have Fuel Stores  13
   Carbohydrates: The Bread of Metabolism          14
   Fats: The Butter of Metabolism                  17
   Carbohydrates and Fats as Fuel Stores           20
   Carbohydrates versus Fats as Fuel Stores        22
   Storing and Mobilising Our Reserves: Just like Making Soap!  23
   Proteins                                       27
   Fuel Stores and Metabolism                      31

3 Metabolic Pathways                              32
   The Concept of Metabolic Pathways              32
   Metabolic Pathways Typically Involve Many Small Steps  32
   Enzymes Bring about Metabolic Pathways          34
CONTENTS

Metabolic Pathways Go from the Twentieth to the Twenty-first Century 37
Metabolic Pathways Underlie any Description of Human Metabolism 42

4 Communication Systems in Human Metabolism 43
The Need for Communication in Human Metabolism 43
The Major Communication Systems 44
It’s My Nerves . . . 44
Hormones Are Remarkable Signals 47
Hormones and Receptors 50
There Is a Large Family of G Protein-coupled Receptors 54
Some Receptors Affect the Synthesis of Proteins from Genes 56
Metabolism and Hormones Begin to Get Confused 57

5 ATP: The Common Currency of Metabolic Energy 59
The Idea of an ‘Energy Currency’ 59
What Is ATP? 60
Metabolism and Combustion 62
Two Ways of Making ATP 62
Mitochondria 64
Cellular Location of Metabolic Pathways 65
Alcohol Metabolism 67
Fatty Acid Breakdown 67
Many Amino Acids also Lead to Acetyl-CoA 69
The Fate of Acetyl-CoA 69
Oxidation and the Citric Acid (Krebs) Cycle 69
Oxidative Phosphorylation 72
One Glucose or Amino Acid Molecule Makes a Lot of ATP: Fatty Acids Even More 75
A Further Uncertainty in ATP Yields 76

6 Metabolism in Daily Life 77
How We Study Human Metabolism 77
Daily Life as Opposed to Acute Stress 80
Before Breakfast: Glucose Metabolism 80
Before Breakfast: Fat Metabolism 84
Amino Acids after Fasting Overnight
The Human Gut (Gastrointestinal Tract)
Toast for Breakfast
Butter on the Toast
Add in Some Protein
The Colon and Human Metabolism
Daily Metabolism and Energy Balance

7 Metabolism Is So Adaptable
Why Our Metabolism Needs to Be Adaptable
Survival during Starvation, and Physical Activity,
Both Need Cooperation between Tissues
Studies of Human Starvation
Metabolic Changes in Starvation: An Overview
Glucose, Insulin, and Fat Mobilisation
Ketone Bodies: Fuel for the Brain
Starvation and Diabetes Contrasted
Protein and Amino Acid Metabolism in Fasting
Slow and Fast Metabolism
Exercise and Physical Activity
Muscles
Fast-twitch Muscles
Slow-twitch Muscles
Communications during Exercise
Fuels Used during Exercise
Fight or Flight
Carbohydrates and Fats as Fuels

8 Metabolic Interactions between Nutrients
Carbohydrate, Fat, and Amino Acid Metabolism
Are Necessarily Inter-connected
Energy Is the Primary Determinant: Fuel Use Adjusts according
to Availability
Glucose Can Make Fat, but Fat Can’t Make Glucose
The Importance of Lipogenesis
Amino Acids Are also Intimately Linked with Glucose and
Fat Metabolism
Glucose, Fat, and Insulin 137
The Glucose Fatty-acid Cycle and Other Mechanisms 139
Longer-term Relationships between Carbohydrate, Fat, and Amino Acid Metabolism 141
Putting This into Perspective: Metabolic Interactions and Daily Life 142

9 Metabolic Disorders 144
Metabolism In and Out of Balance 144
Inherited and Acquired Metabolic Disorders 144
Inherited Disorders of Metabolism: Different Patterns of Inheritance 145
Disorders of Metabolism Inherited in a Mendelian Fashion 146
Polygenic and Acquired Metabolic Disorders: A Grey Area 148
Diabetes: A Widespread Disorder of Metabolism 149
Cardiovascular Disease and Metabolism 153
Cancer and Metabolism 154
Metabolic Disorders: Conclusions 156

Concluding Remarks 157

Summary of Common Misunderstandings 159
References 161
Figure Credits 169
Index 172
Foreword

Metabolism. A term that many people have heard of, but also one that very few would be able to define correctly. Among those who would be able to provide a definition, most would end up using terms from biochemistry such as glycolysis, Krebs cycle, and oxidative phosphorylation, remembering the hard time they had learning all these biochemical reactions and pathways at some point during their studies. This might make you wonder then if the concept of metabolism, and whatever it is about, has any relevance to your everyday life. Well, in this splendid book, Keith Frayn tells you that it does – and why it does. More than this, he explains to you what metabolism is, and that all these reactions and pathways are relevant to your everyday life. Understanding them will make you get a sense of what is going on inside our bodies when we eat food, as well as when we do not; why we may be fatter or thinner than we would have wanted to be; and why sugars and lipids are not bad for us but essential for our life. By describing research on these topics over several decades, Frayn also explains how we came to understand metabolism, and figure out many of the complex ways that our organs are interrelated and interdependent. Reading this book is a rewarding experience, as a lot that you have heard of will suddenly make sense. Frayn paints a beautiful picture that will help you understand why we eat what we eat, what happens to that once we eat it, and how our bodies have evolved to be able to adjust to what is available to eat. In today’s societies in which food tends to be plentiful, this might sound irrelevant. Well, I would argue that exactly because food tends to be plentiful, understanding metabolism is crucial for being able to make appropriate and balanced choices regarding what to eat.

Kostas Kampourakis, Series Editor
Surely not another book about metabolism? I can almost hear it being said. There seems to be a plethora of books at present about how to prevent oneself becoming obese, how to lose weight if one has already become so, what one should eat, and especially what one should not eat. There are books about the importance, or otherwise, of exercise for maintaining weight and health, and books about how to live longer by eating the diet of our palaeolithic ancestors or our near-relations in the animal world.

But none of these really addresses the field that biochemists know as intermediary metabolism. That term refers to the chemical processes that occur within our bodies – mostly within our cells – that transform what we eat into useful energy, new bodily constituents, and waste products. Indeed, from a reading of current popular science on the topic of metabolism, you might well have the impression that ‘metabolism’ refers just to the ‘burning’ of foodstuffs with the result either of weight loss or weight gain. You would not then appreciate the myriad of chemical reactions that build up the substances of which we are made, break them down again when they are no longer needed, and create safely disposable waste products. Even our DNA, the material of which our genes is made, is formed from chemical building blocks that are the product of such reactions.

Many features of intermediary metabolism must have evolved a very long time ago, since they are common to all life forms – from bacteria to mammals (Chapter 1). But it seems natural for us to have a particular interest in our own metabolism – human metabolism. And there is good reason for that. What goes on inside us is a product not just of chemical reactions, but of a flow of information between different body parts regulating just what happens and
when – so that when I have just eaten a big meal, my cells begin to store nutrients, and when I have not eaten for some time, they will begin to release nutrients from these stores (Chapters 2 and 3). Such information flow, called metabolic regulation, is a product largely of our hormonal and nervous systems (Chapter 4).

If there is one feature of intermediary, or cellular, metabolism that is widely known it is perhaps the so-called Krebs cycle, more commonly called by scientists the citric acid cycle, discovered by Hans Krebs (later Professor Sir Hans Krebs). But even those who know the term may well not appreciate just what this assembly of chemical reactions does. It can be seen as the ‘final common pathway’ by which all nutrients are broken down, and linked to the release of energy in a form that can be used by cells for all the processes that require it (Chapter 5).

The really wonderful – and often not appreciated – feature of our metabolism is that it is active, and changing, all the time: when you eat breakfast after fasting overnight, metabolism changes quickly; when you start to exercise, it changes even more quickly. During a typical day, chemical reactions in our cells are being accelerated and slowed down in a highly coordinated manner, enabling us to continue leading our daily lives without giving this matter any thought whatsoever (Chapter 6). But I rather hope that, once you understand what these changes entail, you might think about them more than you probably do at present. Changes in metabolism, as just noted, are especially marked during exercise, when our muscles require a supply of energy, that may come from within the muscles’ own cells, or may be brought in the blood from other tissues, especially our fat stores and our liver. However we measure ‘metabolism’, there is no doubt that it is going faster when we are exercising than when we are at rest. But the opposite is true in starvation. When the body is deprived of nutrients, then metabolism is suppressed, conserving the precious stores that we have of metabolic fuels. Our carbohydrate stores are especially precious, the proteins of which our bodies are mostly built even more so, and metabolic mechanisms come into play to preserve these for as long as possible whilst living off our usually plentiful fat stores. The way these changes are brought about in starvation and in exercise is a fascinating aspect of our metabolism that presumably evolved to allow our ancestors to chase, or run from, other animals, and to survive even when no food was forthcoming (Chapter 7).
There is a tendency nowadays to regard carbohydrates, fats, and proteins as separate entities which can each be considered in isolation. This cannot be the view of anyone who has seriously studied human metabolism. The metabolic fates of the three major energy-providing nutrients are, of necessity, intimately intertwined. Our bodies are all the time drawing upon individual nutrients for particular needs: indeed, each of our tissues has its own preferences for particular fuels at different times. And all these requirements must be coordinated. Metabolic scientists now understand many ways in which the metabolic fates of the nutrients inter-relate. At a very basic level, all energy-providing nutrients, including alcohol, feed into the same cellular mechanism for final disposal, the citric acid (or Krebs) cycle, mentioned earlier. They have to share this pathway, and, just like family members sharing a bathtub, they cannot all get in at once. In Chapter 8 we will look at the mechanisms that prevent overcrowding.

But of course, like any other finely tuned system, things can go wrong. Many diseases involve disturbances in one or more of the myriad of metabolic processes that keep us going. Some of these are inherited very directly from our parents. Others are the result of our environment, but most are a combination of both influences. There are fairly common examples of disorders in the metabolism of carbohydrates, fats, and proteins (or the amino acids that make up proteins), and there are more complex conditions that may involve all three, diabetes mellitus (commonly just called diabetes) being one of these. What is more, metabolic changes may underlie common diseases such as cardiovascular disease (e.g. heart attack, stroke) and even cancer (Chapter 9).

I consider myself very lucky to have been able to spend my career investigating something that I find so intensely interesting – human metabolism. About half-way through my career, I was tempted to write down my views of this field so I could ‘spread the word’. The result was an undergraduate textbook, then called Metabolic Regulation: A Human Perspective. This book has proved to be popular for students and researchers in a variety of fields, and the current, fourth edition, is now called Human Metabolism: A Regulatory Perspective (written with R. D. Evans). But these books are not really ‘popular science’, as some reviews attest (e.g. ‘Whoops! I requested this book not realising it was a textbook, I thought it would be a bit more (dare I say it?) dummed down. Not that I’m stupid, but this just isn’t my field . . .’). So, this book, Understanding Human Metabolism, is now my attempt to
present some of the wonder of human metabolism to a wider audience. My aims are twofold. Firstly, I would like others to share my amazement at this wonderful system, the result of millions of years of evolution, and underpinning our daily lives. But, secondly, I really do believe that if more people were to understand just how their metabolism works, we might hear less of the simplistic views on diet and lifestyle that are so often peddled in the media.
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This is my first book aimed specifically at the non-scientist, and a number of
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and steering me in the right direction, including my wife Theresa and my
daughter Liz, and my friend Nick Havely of the University of York, an expert
in fourteenth-century Italian, French, and English literature: a real test of my
comprehensibility. I will dedicate this book, though, to my grandchildren,
Rayya, Alastair, Jibreel, Daniel, and Laith, in the hope it may inspire them to
an interest in science and medicine.