PROF. MUSTAFA DJAMGOZ
& PROF. JANE PLANT

ANTI-CANCER EXPERTS, IMPERIAL COLLEGE LONDON

beat cancer

The 10-step plan to help you overcome and prevent cancer

'Jane has helped innumerable women and men … not just stopping cancer but preventing it returning'
The Telegraph

Contents

About the Book

Regain control of your life and your health

In this major new book, leading cancer experts Professor Mustafa Djamgoz and Professor Jane Plant present a proven 10-step programme to help you beat cancer. Their cutting-edge plan covers every aspect, including:

- The latest essential information about cancer – what it is, what causes it and how to prevent it
- A thorough review of all the conventional and complementary treatments available
- The lifestyle changes you can make to defend your body

With *Beat Cancer* you'll be ready to tackle your diagnosis and stay in remission.

About the Authors

MUSTAFA DJAMGOZ is one of the UK's foremost cancer researchers and the Professor of Cancer Biology at Imperial College London. His work has won numerous awards, including the presitigious Huxley Memorial Medal.

JANE PLANT has been awarded national and international awards for her work on environmental causes of cancer. The bestselling author of *Your Life in Your Hands* and *The Plant Programme*, Jane is herself a cancer survivor.

beat cancer

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PROF. MUSTAFA DJAMGOZ
& PROF. JANE PLANT

Vermilion
LONDON

We dedicate this book to Sabire and Peter for all their love and support, not just during the writing but over the many years of our working lives.

Mustafa Djamgoz and Jane Plant

foreword

This book is important and deserves to be taken seriously. It aims to empower all of us to cope better with cancer by providing us with the latest science written in accessible English. That means research that has been peer-reviewed and published in reputable international journals – in other words, the best. This book is the work of two eminent professors from Imperial College London, Mustafa Djamgoz, Professor of Cancer Biology, and Jane Plant, Professor of Geochemistry, who specialises in studying carcinogens such as arsenic in the environment. Jane has survived six episodes of breast cancer going back to 1987 when she was 42 years old. She is now almost 70 and is the picture of health with her cancer once again in remission.

The book is divided into ten steps designed to help you understand, prevent and manage cancer. The first step explains the exciting new findings about what cancer cells really are and what they do. In particular, it explains the increasingly important science of *epigenetics* and the *stem cell* characteristics of cancer. These are giving us new strategies to beat the disease and even to avoid it altogether. The rest of the book aims to help all of us (and I hope this includes medical professionals too) to develop an integrated approach to dealing with the disease. Hence it demonstrates how to combine the best conventional medical treatments to treat cancer with complementary therapies, exercise regimes and stress management to help healing in the longer term.

This is not a conventional cancer book. You will find many of the things you read illuminating; some of the information may be surprising and even, at times, shocking. However, all of the information is backed up by scientific research and fully referenced.

I recommend the book highly not only to cancer patients and their supporters but also to health professionals and administrators. Only by working together, with the patient as an integral part of the team, will real progress be made. I hope they will read the book and take on board its key messages to help us all to beat cancer.

Professor Sir Graeme Catto, MD, FRCP, FRSE
President, College of Medicine
Former President, General Medical Council
and Vice Principal, King's College London.

welcome

You may be looking at this book because you or someone you love has been diagnosed with cancer and you want to do everything possible to regain control of your health and life or that of your loved one. This book is designed to help you do just that. It should also be helpful for those who do not have the disease but wish to ensure that they do everything possible to reduce their risk of cancer, especially if they are in a high-risk group such as those with a family history of the disease. We want to help you to understand what cancer is, how it can be prevented and treated, and what you can do to help yourself. We want to help you to avoid developing cancer and, for those who already have the condition, to make sure that your medical treatment has the best possible chance of success. We aim to give you the best information based on the latest peer-reviewed scientific and medical literature and make it easily accessible to everyone.

The book is important because cancer is now a global problem and very much a part of modern life. In the West, our lifetime risk of developing it is now more than one in three and rising.[1] There can be few of us who have not been touched by the disease in some way – if not personally, then among our family and friends.

One point is especially important. Being diagnosed with cancer is no longer an inevitable death sentence. Many cancers can be treated. But treatment is not just about what the doctors do *to* you. It is also about how you work *with* your doctors – and how *they* work with you. Making

sure your body is as fit as possible can make a real difference in fighting the condition. We aim to help those diagnosed with cancer to put their disease into remission using changes in diet and lifestyle, in combination with conventional treatment.

the story of this book

This book sprang from our joint desire to enable people affected by, or at risk of, cancer to do everything possible to protect themselves. Mustafa and Jane are experienced scientists working on cancer biology and environmental pollutants, respectively, at Imperial College London, one of the most highly rated universities in the world. Much of Mustafa's work is concerned with developing new and innovative treatments that could prevent cancer cells from spreading through the body. Such treatments have the potential to enable patients even with advanced cancer to live with their disease, in the same way that people live with diabetes, asthma and other chronic diseases. Jane is an international authority on hazardous substances, especially carcinogens (cancer-causing substances) such as arsenic,[2] radioactive elements and hormone-disrupting chemicals found in pharmaceuticals, plasticisers, pesticides and detergents.[3] Her research is aimed at reducing their risk to human health. Until recently, she chaired the UK Government's Advisory Committee on Hazardous Substances. Jane also has a very personal interest in cancer prevention as she has, against all the odds, overcome breast cancer an incredible six times in the last 28 years.

Jane's story of defeating breast cancer

Jane first developed breast cancer in 1987. She had a mastectomy, but the cancer returned four times over the next five years, each time spreading to lymph nodes near

the original cancer. In 1993, with a secondary cancer the size of an egg in her neck, she was told the chemotherapy was not working and she had only two months to live. That was horrific news. Jane was just as frightened as any of us would be, but as a scientist her immediate instinct was to research to find out why she had contracted cancer and what she could do to help herself. She and her husband had worked in China and knew that Chinese women there had very low rates of breast cancer at that time. They discovered that breast cancer was also rare in other oriental countries such as Japan and Thailand. Yet women from these places appeared to be at just as much risk as American or European women when they moved to the West. The only differences seemed to be diet and lifestyle. We will tell you more about what Jane discovered later in this book and how her work with Mustafa is providing clear guidelines underpinned by sound science to help beat cancer.

Jane changed to an Asian-type diet overnight. That seemed to allow the chemotherapy to kick in. Within days, her cancer was shrinking and within six weeks, there was no sign of it. Until 2011 she had remained free of the disease for almost 20 years and had published her story and findings in her international bestselling book *Your Life in Your Hands*.[4]

In December 2011, however, she was diagnosed again with breast cancer. At the time, she had a large lump beneath her collar bone which had spread over an area of 80 cm^2, another secondary tumour in the lining of her right lung, and small secondary tumours throughout her right lung. She realised just how lax she had become about her diet and lifestyle. She returned immediately to her Asian-type[5] diet with a daily exercise routine and used meditation and other stress-management techniques in combination with the tiny dose of letrozole prescribed by her oncologist.

After only three weeks the fluid had cleared from her lung and the lump beneath her collar bone had reduced to an area of less than 36 cm^2. By July Jane was told once again that her cancer was in remission.

Jane has lived nearly half her adult life with breast cancer. It was her personal experience that led her to undertake research into the disease alongside her day job and she is convinced that an approach that integrates the best of conventional medicine with a good diet and lifestyle is essential to beating cancer. She has written a number of books about cancer[6] for the general reader and runs a website, www.cancersupportinternational.com, which carries useful information about cancer.

Mustafa's research – neuroscience solutions to cancer!

Mustafa trained in neuroscience and studied the workings of the brain for some 25 years before becoming interested in cancer! He is the first to investigate systematically electrical signals in cancer cells and has discovered that, in order to spread, cancer cells become electrically excitable and hyperactive, rather like nerve cells in an out-of-control epileptic brain. He is now involved in developing new and innovative treatments based on that research and already a new drug is in preparation for clinical trial. The primary aim of his research is to control cancer non-toxically, that is without chemotherapy! He has also established a small charity, Pro-Cancer Research Fund (PCRF) that supports the new research and runs the Amber Care Centre, a drop-in facility in north London for cancer patients and their families.

Jane and Mustafa were introduced to each other about 10 years ago by a colleague at Imperial. As Jane learnt more and more about Mustafa's research, he developed an interest in Jane's work on carcinogens in the environment

and her research into the role of dietary and lifestyle factors. We have thus come to the study of cancer from different directions – Mustafa from the background of a lab-based scientist and Jane from field and laboratory work in many countries trying to identify links between the environment and human health. It is remarkable how, from these different directions, we have reached very similar conclusions. Cancer is not just bad luck: we know more about its causes than ever before. For many sufferers, it no longer needs to be a death sentence. Even in the case of aggressive metastatic cancer we now know the sequence of events involved. Already, a lot can be done to prevent and treat cancer, at least to the point where we can live with it, as the increasing survival rates demonstrate. For instance, more than three-quarters of women diagnosed with breast cancer now survive for 10 years or more. In the 1970s, just 44 per cent survived for this length of time.[7] There has been a similar increase in survival rates for men with prostate cancer. This may be linked to better testing, enabling the disease to be identified at an earlier stage. Understanding the processes involved in the development and spread of cancer explains why Jane's approach to complementing her medical treatment with a change in lifestyle and diet works and why she is still here 25 years after her first diagnosis of breast cancer.

We both understand just how daunting a cancer diagnosis can be and how hard the process of treatment and recovery can be. In addition to carrying out our research, we both work through our own charities, websites and other organisations to help cancer patients personally. We understand the humanity needed to help people to deal with this most dreaded of diseases and to put it into remission.

This book brings together our expertise to give you the best possible evidence-based advice.

There is a great deal we can do for ourselves in our everyday lives, both to avoid the disease and to support medical treatment in helping our bodies to fight it. The book explains the latest scientific thinking, building on evidence from the work of distinguished international scientists. Some of the ideas are yet to be accepted widely, but they are based on impeccable science. Not surprisingly, you will come across words and concepts you may not be familiar with. We aim to explain these clearly as they occur. More than anything, though, the book is the product of Jane's and Mustafa's many discussions with each other – and with their brilliant students.

how to use the book

Clinical medicine is necessarily conservative! It takes a long time for new ideas to be accepted. Even when adopted, clinical trials may take many months before evidence emerges and new drugs or procedures enter clinical practice. Increasingly, however, cancer-support centres such as the Maggie's Cancer Caring Centres in our major hospitals are using a more integrated approach to cancer treatment. Throughout this book, we have adopted an integrated evidence-based approach to preventing and treating cancer, combining conventional treatment with the best complementary therapies such as diet and exercise. The information and advice we give are based predominantly on peer-reviewed publications, and each of the chapters in the book has been critically assessed by two or more experts in the field. In any case, the whole of our stance is derived from sound established scientific principles. References are given throughout the book, so it is possible to go deeper into the various topics being covered, should you or your doctors wish.

This book is divided into 10 chapters, each representing one step on the path to living a healthy life – ideally without cancer! To have any chance of preventing cancer or beating it and keeping it in remission, we need to understand what cancer is, how it develops and progresses, what treatments are available and how we can make sure our bodies are in the best possible state to combat it. The first of our 10 steps is a modern, rational, scientific explanation of what cancer is, and we then take you through all aspects of conventional treatments, complementary therapies and dietary and lifestyle factors. We hope you will find the steps helpful in beating or controlling the disease or – even better – avoiding it. Each chapter or step is written as a stand-alone and can be read on its own. Or you may wish to read the whole book through to learn all about the best ways to beat the disease. The book includes science facts in boxes, which some readers may wish to skip or come back to later. However you choose to use the book, we wish you well on your mission to understand and beat cancer.

step 1

inform yourself

If you or a loved one has been diagnosed with cancer, or even if you simply want to do all you can to avoid it, your first step is to understand what cancer is and how you can help your body fight it. The knowledge you gain here will help you to take action to reduce your risk. If you already have a diagnosis, you will be better able to understand what your doctors tell you, know what questions to ask and then decide, with them, on the choice of treatments to ensure the best possible outcome.

Although cancer is a complex disease modern research is rapidly revealing its secrets. It was not so long ago that the stigma attached to the ‘C word’ or the ‘big C’ meant that people would talk about it in hushed tones behind closed doors. Thankfully times have changed – and so has the outlook for people with cancer. Cancer is no longer the inevitable killer it once was. Although between a third and half of us will develop cancer at some time in our lives, our chances of survival are better than ever, particularly when cancer is diagnosed early. And the good news is that prevention is fast becoming a reality. What we hope to do in this book is explain what you can do in your everyday life to boost your odds of beating cancer.

about cancer

Cancer is not a single disease. There are more than two hundred different types of cancer that can affect various parts of the body. Even cancers of specific organs, like breast or lung, may include several different subtypes, which behave differently and need different treatments. Breast cancers, for example, can develop in different parts of the breast. In some, the cancer's growth is driven by hormones, while in others it is not. Cancers also vary in their biochemical properties and in how quickly they may grow and spread. Hardly surprising then that there is no single treatment or therapy that works for all cancers or even cancers of individual organs.

Doctors will never say that cancer is cured; only that it is in *remission*. If even a single cell remains after treatment, it can replicate and start the cancer growing again. For that reason, cancer is now regarded by many doctors as a chronic disease, much like diabetes or asthma.[1]

Cancer types

Cancers are often grouped by the tissue where they originated. You may come across these names if you or someone you know has a diagnosis.

- *Carcinomas* develop in the tissues that cover external and internal body surfaces and are made up of what are called *epithelial* cells. Carcinomas are the most common cancers and include lung, breast and colon (or bowel) cancer.
- *Sarcomas* begin in the cells of the supportive tissues in the body, such as bone, connective tissue, muscle, fat and cartilage.
- *Lymphomas* develop in the lymph nodes and the body's immune system.
- *Leukaemias* develop in blood cells in the bone marrow and tend to be found in large numbers in the blood.

Age matters

Every year, more than 300,000 people in the UK develop cancer for the first time[2] – three-quarters of them in people aged 60 or over and one-third in the over 75s. Only one in

10 are diagnosed in people aged 25–49. The risk of most cancers increases with age as your body experiences wear and tear and is bombarded by undesirable environmental factors. A small number of cancers affect children, notably some leukaemias, but childhood cancer is thankfully rare with around only 1,500 new cases each year in the UK.[3]

Cancer and culture

Although cancer affects people the world over, there are dramatic differences between the types of cancer common in the richer West – Europe, including the UK, and USA – and those which are more likely to affect people in developing countries. The affluent West and developing nations are poles apart in cancer, as in so much else. The difference is so stark that we now refer to cancers of affluence and cancers of poverty (see Figure 1.1).[4]

We can learn a lot from these differences and by studying different communities with markedly different diets and cultures. In the West, for example, hormone-related cancers such as breast and prostate are among the most common. But in poorer countries, cancers caused by infection – stomach, liver and cervical cancers – are far more prevalent. The proportion of cancers caused by viruses is three times greater in East Asia than it is in the UK, and even higher in many African countries, yet hormone-related cancers are less common, even in relatively rich countries like Japan. Ever since reliable cancer registries began to be kept in the 1950s, we have seen a dramatic difference between oriental and Western countries in the numbers affected by breast and prostate cancer. The incidence of prostate cancer in Japan, for instance, is one of the lowest in the world. Yet when Japanese people live in the West and eat a Western diet, their risk of these cancers rapidly rises to the same level as the locals. That suggests that the cause cannot be wholly genetic or hereditary, it must also be related to lifestyle. In fact, the World Health Organisation (WHO) say that 30–40 per cent of cancers can be prevented if we change our diet to something more like that in many Eastern countries.[5] Sadly, the spread of the Western diet and lifestyle is having a dramatic impact on cancer rates. The latest data from the International Agency for Research on Cancer shows that Eastern countries are rapidly catching up with the West. We shall talk in more detail about the role of diet and lifestyle in Steps 5, 6, 7 and 8.

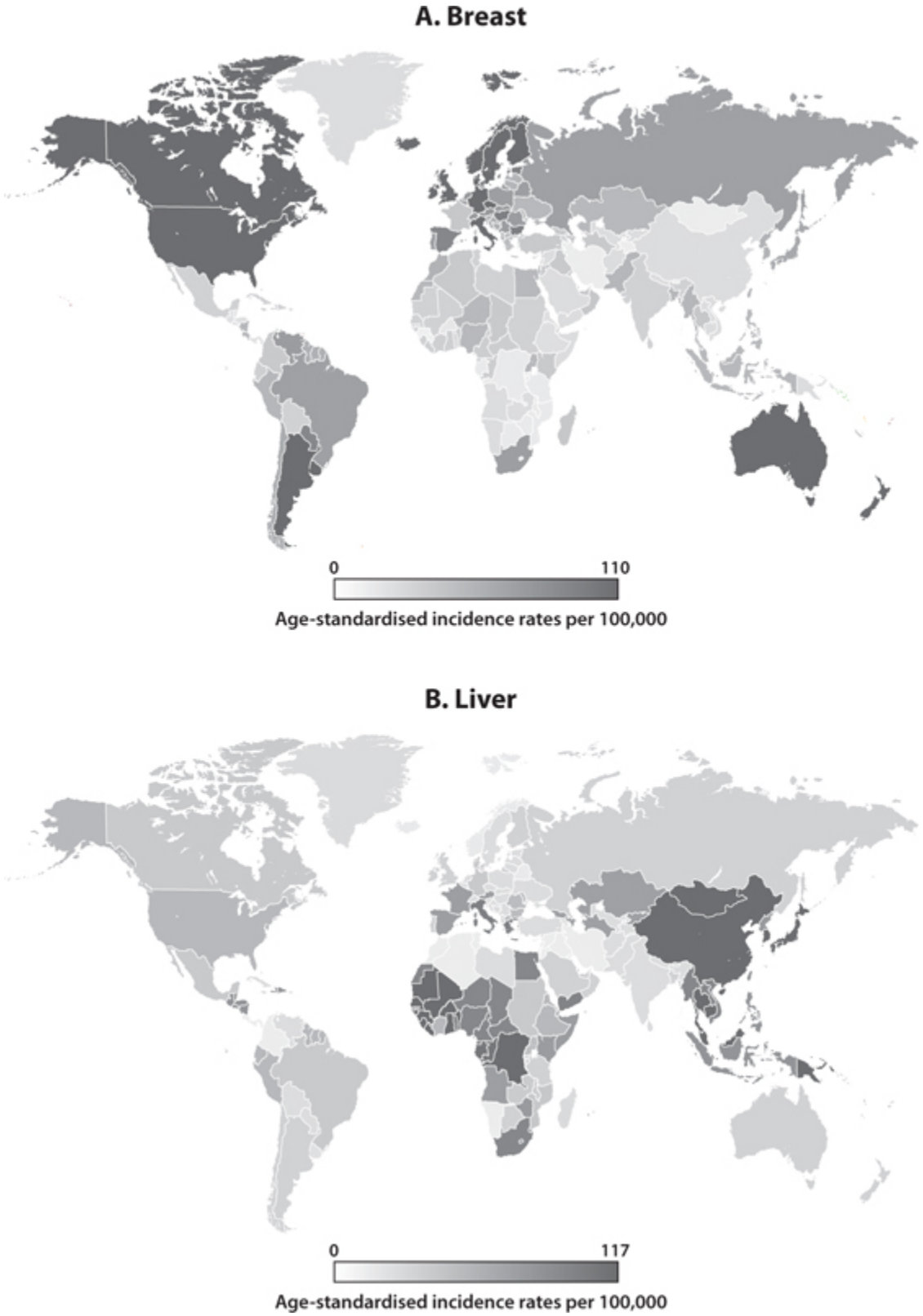

Figure 1.1 *Breast (A) and liver (B) cancers as examples of cancers of affluence and poverty, respectively. The darker the shading, the higher the incidence.*

why cancer develops – cells behaving badly

Cancer is not a new disease. In fact, Hippocrates first described and named it 2,500 years ago in ancient Greece. He called it *karkinos*, the ancient Greek word for crab, perhaps because he thought cancer was an alien organism invading the body. We now know that is wrong. Cancer is in fact just our own cells behaving badly.[6]

How your body works

All the tissues and structures within our bodies are made up of more than 100 trillion (100 followed by 12 zeros) tiny cells, most of which are constantly reproducing themselves (or we would simply wear out). Different tissues are made up of different types of specialised cells. For instance, white blood cells are different from red blood cells, and both are different from bone or muscle cells. Many tissues also contain specialised stem cells which are important for the growth of our tissues as we mature, as well as for tissue regeneration following injury or damage. During wound healing, for example, skin cells and skin stem cells multiply to repair the damage and move to close the gap. In a healthy body, biochemical signals instruct cells when to start and stop growing or tell them they should move or stop so that tissues and organs can be repaired as necessary and stay in good shape.

When things go wrong

Cancer happens when something goes wrong with the systems that regulate these processes so that cells lose control and start multiplying in an uncontrolled way. When this happens it results in a lump which may be benign or

cancerous. Benign lumps are different to cancers – they normally grow slowly, do not spread and only cause problems if they grow very large or put pressure on the tissue where they are growing.

If the cells are cancerous they can also invade the surrounding healthy tissue – known as 'local spread' – and can spread to other more distant parts of the body – a process known as 'metastasis'. If, for example, breast cancer spreads to the lungs, the cancer cells are still breast cancer cells, not lung cancer. It is this ability to spread that makes cancer so dangerous – in fact most cancer deaths result from metastatic disease, not the original (primary) tumour. That is why screening and early diagnosis are both so important.

What makes cancer cells different?

Although there are many different types of cancer, their cells have certain common characteristics that set them apart from normal cells. Cancer researchers Douglas Hanahan and Robert Weinberg defined the 'hallmarks of cancer',[7, 8] which show just how different they are to normal cells (see table).

Normal cells	Cancer cells
Only divide when signalled to do so by the body's biochemical control system. Another signal tells them when to stop dividing.	Keep growing and multiplying in an uncontrolled way because of signalling abnormalities and ignore instructions that tell them to stop.
When cells are damaged a molecular brake halts cell division until they are	The molecular brake does not work and they lack the

repaired. If they are damaged beyond repair, they are programmed to die (apoptosis) so damaged cells which could harm nearby healthy cells are eliminated.	mechanism that triggers the process of apoptosis.
Can divide only a limited number of times (50–70) before they wear out and die.	Can keep dividing indefinitely.
They are inactivated when they touch each other (known as ‘contact inhibition’).	They remain active and keep reproducing despite contact with other cells around them.
Metabolise glucose to produce energy in the mitochondria using oxygen.	Metabolise glucose anaerobically (without oxygen) in the main body of the cell and consume far more glucose than normal cells.
Do not travel – e.g. breast cells stay in the breast, lung cells stay in the lung.	Can travel via the blood stream and lymphatic system to other parts of the body where they can develop secondary tumours.

Angiogenesis

Oxygen is essential for the survival of all cells, but once a growing tumour reaches a size of 0.5–1 millimetre, it becomes too big for oxygen to diffuse into it from existing blood vessels. *Angiogenesis* is the ability of cancer cells to create and attract new blood vessels, so that they can obtain a continuous supply of oxygen and other nutrients and eliminate the waste products generated during their growth.

Why doesn’t our immune system destroy cancer cells?

Our immune system quite simply is not efficient in detecting cancer because tumours consist of our own (albeit damaged) cells. This also makes developing cancer vaccines difficult. However, vaccines have been developed against at least some cancer-causing viruses such as the human papilloma virus which is associated with cervical cancer.

How the lymphatic system works

As your blood circulates, a colourless fluid (*lymph*) leaks out of the capillaries into tissues before draining into fine *lymph vessels*. Lymph contains large numbers of several types of white blood cells called *lymphocytes*, which are important in fighting disease. Lymph generally moves around the body more slowly than blood because it is not pumped around by the heart.

The small lymph vessels join together to form larger tubes which pass through *lymph glands* (or *nodes*) in various parts of the body including the armpits, neck, groin and abdomen. They vary from the size of a pinhead to that of a baked bean, and their number varies from person to person; there are usually between 15 and 30 in the armpit, for instance. These lymph nodes trap and try to destroy anything harmful, such as bacteria and viruses. Sometimes they cannot do this immediately, and the lymph nodes swell and become painful in response to the infection. The immune system includes specialist organs such as the tonsils, adenoids, spleen and thymus which have important roles in fighting disease.

The lymphatic system also provides a route – along with blood vessels – for cancer cells to spread. A type of cancer called *lymphoma* originates in the lymph nodes themselves; they swell, but are usually painless. There are many other reasons for such symptoms, but if you can feel painless but swollen lymph glands, it is important to have them checked by your doctor.

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how cancer develops

'Solid' tumours that develop as lumps of cancer cells like breast or bowel cancer (as opposed to 'non-solid' cancers of the blood – leukaemias) have three main stages of development (see Figure 1.2).[9]

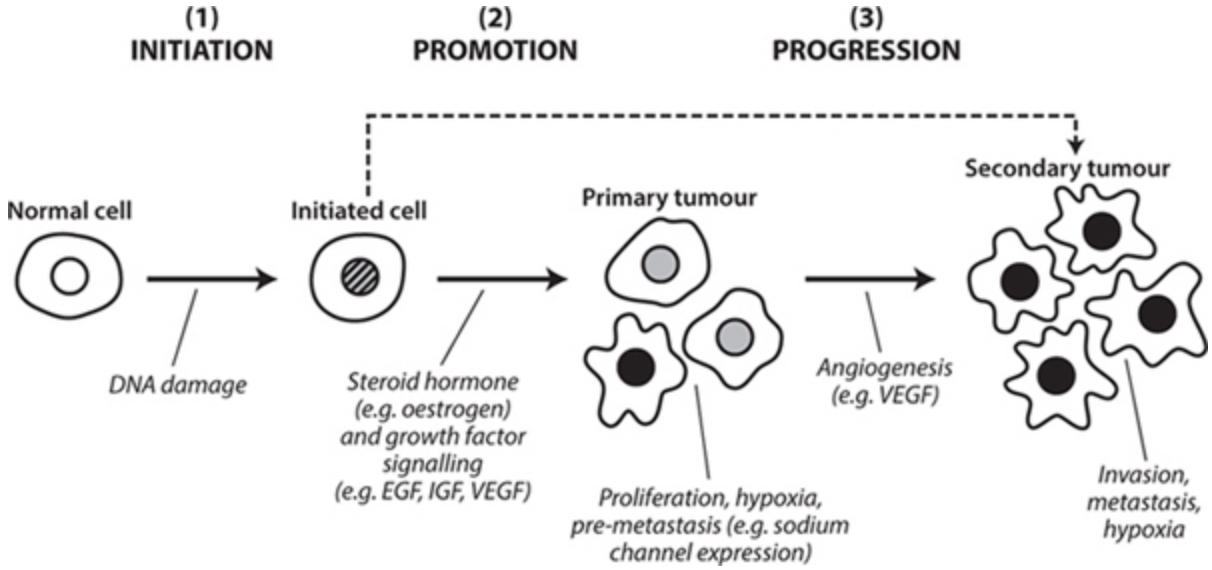

Figure 1.2 *The three main stages of cancer*.

- *Initiation* – when the DNA (deoxyribonucleic acid) of the genes that control cell reproduction (known as 'cell-cycle genes') is damaged, for example by environmental factors such as ionising radiation or tobacco smoke.
- *Promotion* – when initiated cells multiply to form a collection of cancer cells – 'primary tumour'.
- *Progression* – when the primary tumour develops further and starts to spread, initially locally and then through the body – metastasis.

However, it is possible in some cancers, especially aggressive ones, to go direct from initiation to progression.

The promotion of initiated cancer cells

the promotion stage is when the primary tumour has started growing and cancer cells are multiplying. In some cancers, notably cancers of the blood, there is no solid tumour, just large numbers of circulating cancer cells. Scientists believe that what happens at the promotion stage is crucial in determining whether the earliest cancer cells – the initiated cells – survive and go on to become a tumour. The process is rather like watering and fertilising (initiated) cancer 'seeds'[10] or providing oxygen to (initiated) cancer 'sparks'.[11] Increasingly research is linking cancer promotion to the presence of high levels of proteins called growth factors circulating in the body and, with hormone-dependent cancers, to high levels of hormones such as oestrogen and testosterone. As we will learn later in this chapter both growth factors and hormones normally act as chemical messengers in the body but they can promote cancer if their levels are out of balance. By changing the body's biochemistry, therefore, diet can impact upon hormones, growth factors and hence cancer (see Step 5).

How cancer spreads

We have learnt that cancer is the uncontrolled growth of cells and tissues. It can occur in almost any part of the body, but as long as it stays in the place where it developed it remains a primary tumour that can usually be removed by surgery and poses no further danger. It is cancers that spread to other parts of the body and cause secondary tumours (metastases) that are the most dangerous.

So how does this happen?

We used to think that cells in the primary tumour had to develop the ability to spread, and that this happened as they kept dividing and repeating the mistakes that had initially caused the cancer. But the recent discovery that a cell that has just become cancerous may *already* have the

gene combination it needs to metastasise has challenged this view. In fact, we now know that sometimes metastatic disease occurs without a primary tumour being clinically identifiable. A common example of this is the smoking-related small-cell lung cancer.

Metastasis

Once they are able to spread, some cancer cells detach from each other, break off from the tissue where they are growing and ultimately enter the body's circulation system. Where the primary tumour is very close to the circulatory system they can enter directly – breast cancer, for example, spreads mechanically first to the under-arm lymph glands, which are close to the breast ducts where most breast cancers arise.

Alternatively, cancer cells can enter blood vessels – a process called *intravasation* where the cancer cells have to squeeze through tight spaces in the blood vessel wall. Once in the circulation system, they can survive for months, even years. Many of them will die – killed off by the white blood cells or battered by the fast flowing blood – it has been estimated that only one in every 10,000 cancer cells entering the blood circulation ultimately survives. That's the good news. But if even a few cells survive and reach their target they can squeeze back through a blood vessel wall (extravasation) into the tissue of any organ close by. Different cancer cells tend to lodge at different organs – for example, breast and prostate cancer often spread to bone. Once they find the right environment the cells can settle, start multiplying again and form secondary tumours.

However, not all these extravasating cancer cells go on to form full-blown secondary tumours. Quite often, they form only 'micro-metastases' – too tiny to be detected, even on a scan – which can remain dormant for years. In essence, they remain in hibernation, possibly because of signals they receive from the primary tumour that prevent them developing a supply of new blood vessels that would enable them to grow – known as angiogenesis.[12]

The primary tumour can send out signals that either promote the formation of new blood vessels or inhibit it. It appears that some primary tumours may stop secondary tumours from fully developing by releasing inhibitory signals. This is rather like the behaviour of a parasite which wants to keep its host alive for as long as possible.[13]

This is crucial when it comes to treatment. The oncologist must always take account of the fact that there may be micro-metastases when deciding on the best treatment. It also means that it is not always the best thing to operate and remove the primary tumour as this could be sending out inhibitory signals and removing it may clear the way for micro-metastases to grow and form secondary tumours. All this reinforces our view that cancer is best

managed by research-active clinicians practising in teaching or specialist hospitals or with links to such hospitals (see Step 3).

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our new understanding

So what triggers cells to become cancerous and grow? The latest research suggests that much of the answer lies in *stem cells*.

The role of stem cells

We have seen that cancer develops when the signals that regulate how cells divide and multiply go wrong, and there is increasing evidence that this involves stem cells.

Stem cells are the body's raw materials – the cells from which all other cells with specialised functions are formed. Embryonic stem cells, the cells found in the very earliest stages of the embryo, are able to become any type of body cell – this is how the embryo develops into a baby. As the embryonic stem cell keeps reproducing, its daughter cells ultimately become heart, brain, bone and many other types of cell. These remarkable embryonic stem cells disappear within a few days of birth. Adult stem cells are found in small numbers in most adult tissues and have a more limited repertoire than embryonic stem cells, linked to the tissue or organ where they are situated. Like regular cells, these specialised stem cells divide to form two identical new cells – so a breast stem cell will divide to produce two breast stem cells, unlike embryonic stem cells, which have the remarkable ability to transform into different cell types. Remarkably, this process may be reversible, at least to some extent, and a recent (2014) paper published in the world-famous journal *Nature* has shown that mature cells may be forced to acquire stemness by being shocked in acid.[14]

What appears to happen as cancer grows is that distorted signals cause some of the new cells created from cell division to switch back into something like their neonatal or embryonic stem-cell form, instead of their specialised adult form.[fn1]

Another characteristic of embryonic stem cells is that they are capable of dividing and renewing themselves for long periods – far longer than ordinary cells which eventually age and die – so they are able to increase their numbers very rapidly. Cancer cells seem to behave in a similar way, so the obvious question is: do embryonic stem cells have a role in the development of cancer?

Scientists argued for more than 10 years about whether cancer stem cells actually exist and, if they do, whether they drive the development of cancer. It was one of the biggest scientific controversies in cancer research. Now three separate studies on mice, all published in 2012, have resolved it.[15] Three groups, working independently – in the USA, Belgium and the Netherlands – looked at brain, skin and intestinal cancers, respectively, and all found direct evidence of stem cells driving cancer growth. The suggestion is that the same is true of all cancers that produce solid tumours.

What this means for cancer treatment

The similarities between cancer stem cells and healthy embryonic stem cells have important implications for treatment. Any therapy that targets cancer stem cells may also attack healthy tissues and cause widespread damage. But if researchers can identify significant differences between normal adult cells and cancer stem cells they may be able to develop therapies that distinguish between them, and target only cancer stem cells, leaving healthy cells untouched.

Like embryonic stem cells, cancer cells have an extraordinary ability to transform themselves. This means that treatments like chemotherapy, which are aimed at killing them, may actually encourage the development of drug-resistant cells which survive treatment and form a new cancer (Figure 1.3). What this means for patients is that, in some cases, aggressive chemotherapy aimed at destroying the cancer may not be the best treatment. In fact, it may be better to control the cancer and stop it from proliferating and spreading rather than trying to kill it outright.

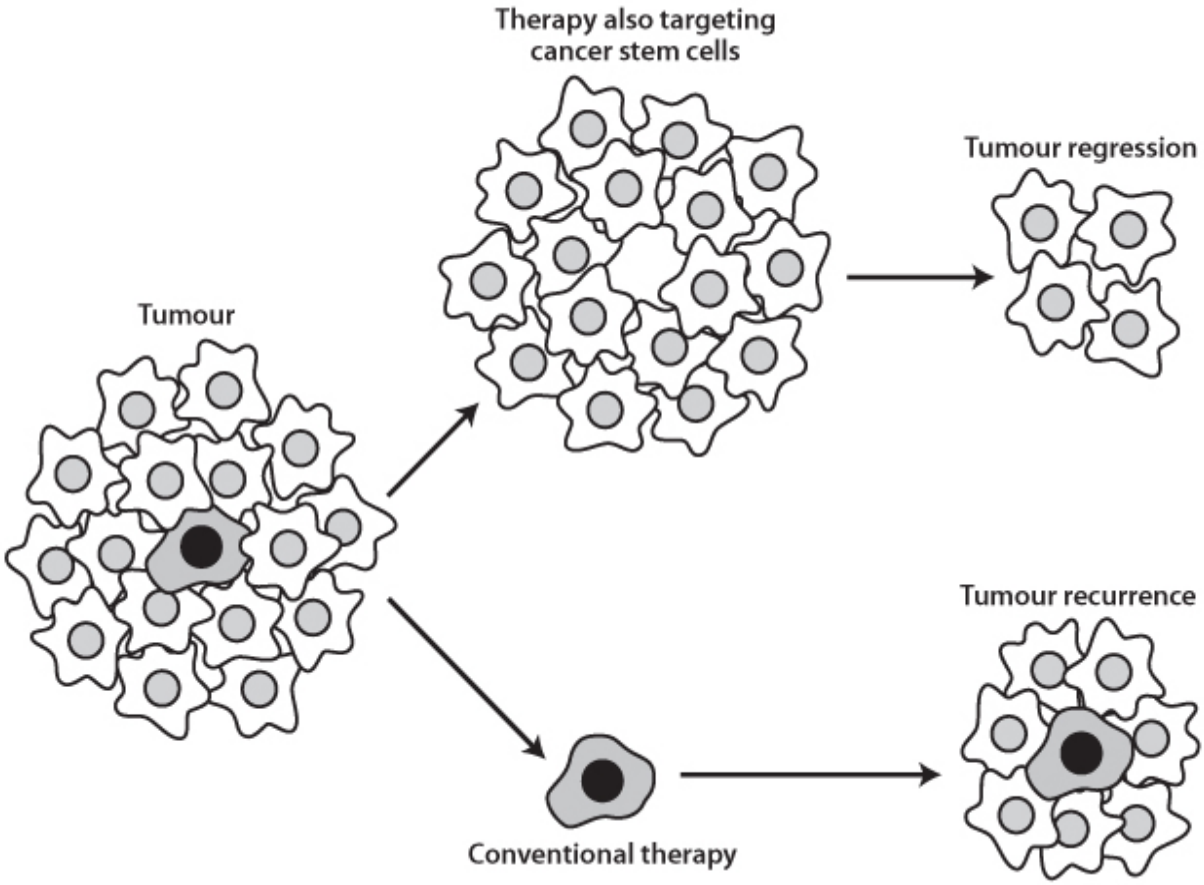

Figure 1.3 *Comparison of conventional chemotherapy with treatment which also target stem cells. Tumour regression is more likely with the latter.*

How good cells turn bad

We have looked at what happens to individual body cells, but now we need to go deeper and discover what happens at the genetic level to change healthy cells into dangerous cancer cells.

DNA provides the basic code for all life on earth. It is the substance that our genes are made of and it produces the proteins in our bodies that carry out all the activities that keep us alive. Our genes are strung out along chromosomes which are found in the nucleus of every cell in our body, except red blood cells which lack a nucleus (Figure 1.4).

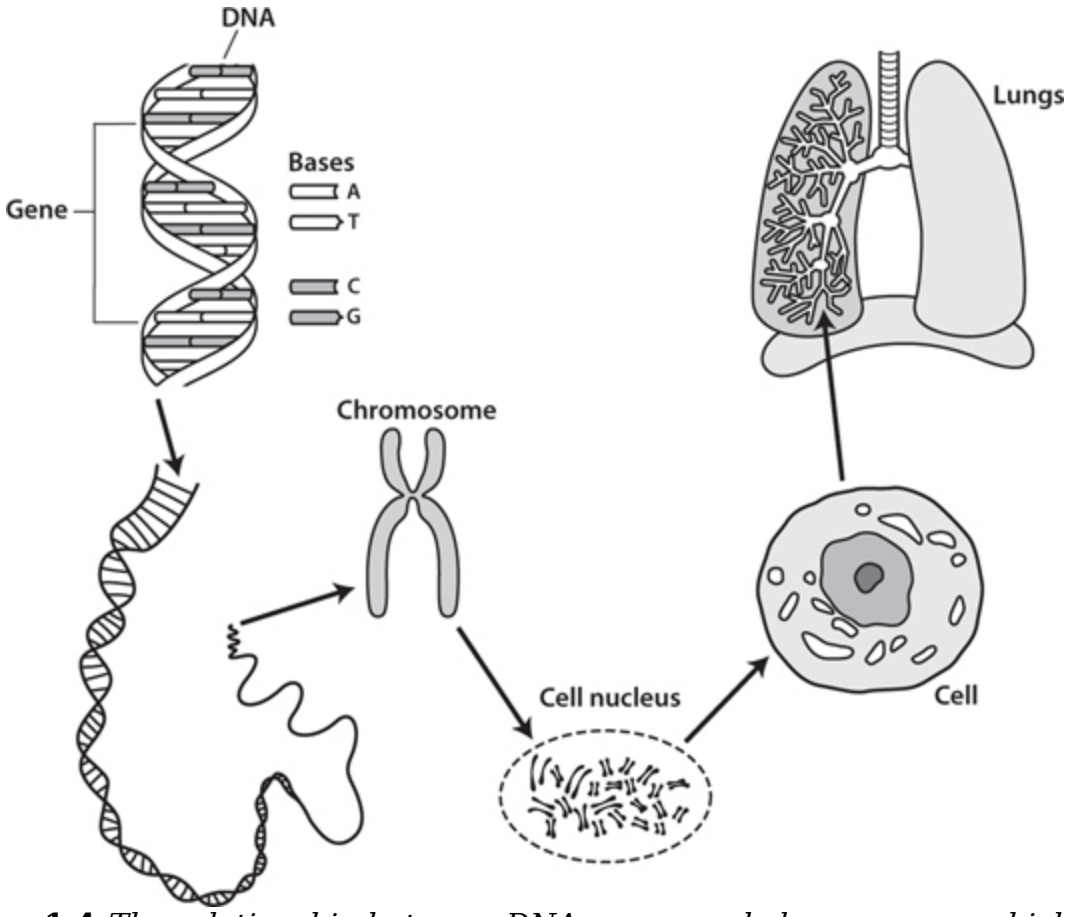

Figure 1.4 *The relationship between DNA, genes and chromosomes which are in the cell nuclei of all the tissues that make up our organs, such as lungs.*

Humans have 23 pairs of chromosomes: one of each pair is inherited from our mother, the other from our father. You might inherit the gene for brown hair from your mother and red hair from your father, in which case your hair will