

INDEX

- ABC transporter superfamily, 188
- ABL1* gene/protein, 80, 86, 182, 231, 252, 275
- acoustic neuroma, 30, 106, 297
glossary, 277
- actin(s), 53, 122, 141, 161, 166, 167
smooth muscle actin, 140
- action potential, 22
glossary, 277
- acute erythroleukaemia, glossary, 277
- acute lymphoblastic leukaemia (ALL), 79, 172, 270–273
BCR-ABL1, 168, 169, 182
chemotherapy, 180
chromosome translocations, 86
ETV6-RUNX1 translocation, 6, 79–81, 83, 84
glossary, 277
mortality, 8
Philadelphia chromosome, 79, 271–272
- acute myeloid leukaemia (AML), 180, 200, 272–273
glossary, 278
IDH mutations, 131
smoking, 32
whole genome sequencing, 215
- acute non-lymphoblastic leukaemia (ANLL), glossary, 278, 292
- acute promyelocytic leukaemia (APL), 6, 80
arsenic trioxide (As₂O₃), 81
glossary, 278
- adaptor proteins, 49, 50, 161, 168
- adenocarcinoma, 108
colon, 95
colorectal, 259, 282
glossary, 277
lung, 216, 254, 255, 258
oesophageal, 263–265, 279
pancreatic, 137, 267
- adenoma, 35, 95, 104, 105
glossary, 277
- adenosine monophosphate (cAMP), 59, 61, 161, 172, 281
- adjuvant/neoadjuvant, 136, 184, 187, 200
glossary, 277
- adult T-cell lymphoma–leukaemia (ATL), 71, 270
glossary, 279
- AfrOx, 14
- age, 4, 11–13
Andorra, life expectancy, 11
Bronze Age, life expectancy, 12
Glasgow, life expectancy, 12
of first childbirth, 7
Swaziland, life expectancy, 12
- Age Standardised Rate (ASR), 4, 6, 9, 16
glossary, 277
- alcohol, 33–35
- allostery, 181
glossary, 277
- alpha particles, 21, 22, 27
- alternative telomere lengthening (ALT), 117
- Alu* sequences, 72
glossary, 277
- Alzheimer's disease, 189, 224
- American Institute for Cancer Research, 39, 42
- amplification
gene, 58, 73, 75–78, 84, 118, 162, 165, 182, 187, 216, 220, 222, 225
signal, 45, 50
- amplification, glossary, 278
- amyotrophic lateral sclerosis, 224
- aneuploidy, 73
glossary, 278
- angiogenesis, 60, 75, 109, 117–121, 124–134, 136, 166, 171–174, 180, 187
- anoikis, 146
glossary, 278
- anti-angiogenic agents, 182–184, 204
- antibody-directed enzyme prodrug therapy (ADEPT), 183
- anti-oxidants, 35, 68
- anti-sense oligodeoxynucleotide (ODN), glossary, 278
- APC* gene/protein, 70, 93, 95, 161, 165, 254, 261
β-catenin, 106, 117, 126, 159, 164, 165, 259
cancer driver, 66, 70, 81, 96, 122, 160, 218, 220–225, 228, 233
mitosis, 55, 56, 95, 117, 165, 235
mutations, 165, 166, 224

Index

- apoptosis (programmed cell death), 57, 90, 91, 99, 108, 111–115, 153–170, 180, 194, 227, 235
- anoikis, 146
- cytochrome c, 90
- glossary, 278
- MYC, 90
- p53, 90
- regulation by HIFs, 126
- ribosomal protein S6 kinase, 235
- suppression by AKT, 176
- therapeutic activation, 188, 195
- apoptotic protease activating factor 1 (APAF1), 114
- aptamer, 184
- glossary, 278
- ARAF* gene, 53, 227, 289
- ARF* gene/protein, 93, 155
- aromatase, 64, 246, 262
- inhibitors
- anastrozole, letrozole, 64, 143
- astrocytoma, 92, 105, 192
- glossary, 278
- ataxia telangiectasia, 94
- glossary, 279
- ATM* gene/protein, 94
- atrial fibrillation, 224
- auto emissions
- breast and lung cancer, 13
- autophagosome, 163
- glossary, 279
- autophagy, 116, 163, 279
- autophagosome, 163
- glossary, 279
- hypoxia, 116
- inhibition, 163, 188
- mTOR, 163
- RAS, 163
- SRC, 168
- autosomal, 88, 92, 93
- glossary, 279
- avian myeloblastosis virus (AMV), 77
- glossary, 278
- avian sarcoma virus (ASV), 71, 170
- glossary, 279
- bacteria, 14, 21, 47, 72, 107, 132, 148, 293
- Barrett's oesophagus, glossary, 264, 279
- basal-type breast cancer, 143, 216, 260–263
- glossary, 279
- basement membrane, 95, 118, 120, 138
- glossary, 279
- basic helix–loop–helix, 55
- glossary, 280
- BCL2* gene/protein family, 253
- anti-apoptosis, 99, 133, 160, 278
- BCL2* micro RNA regulation, 99
- mitochondria, 114, 115
- MYC, 90
- translocation, 86
- BCR-ABL1* gene/protein, 78–79, 81, 85, 169, 182, 233, 234, 272, 312
- ALL, 182
- dasatinib, 182, 234, 245
- driver translocation, 82
- imatinib (Gleevec®), 82, 182, 188, 205, 231, 234, 275
- mRNA biomarker, 231
- mutations, 182
- nilotinib, 182, 234, 245
- signalling, 167–168
- super scaffold protein, 168
- benign tumours, 103–106, 117, 137, 162, 258, 262, 268
- glossary, 280
- beta particles, 21
- bipolar disorder, 224
- birthmarks, moles, 104
- bladder cancer, 107
- mortality, 2, 8
- smoking, 32
- SNPs, 224
- Bloom's syndrome, 78, 94
- glossary, 280
- bowel cancer, *See* colorectal (bowel) cancer
- Bradley, Allan, 89
- BRAF* gene/protein, 54, 220, 227, 297
- inhibition, 226, 228, 233, 234, 245, 247
- melanoma, 106, 214, 290
- signalling, 53
- stomach (gastric) cancer, 259
- brain tumours, 2, 3, 6, 15, 76, 85, 145, 162
- acoustic neuroma, 30
- astrocytoma, 92
- gene amplification, 84
- glioblastoma, 122, 183
- glioma, 30
- IDH1, IDH2 mutations, 130
- medulloblastoma, 170
- mobile phones, 31
- MRI imaging, 193, 199
- BRCA1*, *BRCA2* genes/proteins, 94, 234, 254, 259, 262, 263
- breast cancer, 79, 143, 223
- DNA repair, 93, 94
- synthetic lethality, 225

Index

- breast cancer, 260–263
 alcohol, 33
 Avastin® (bevacizumab), 120, 183, 234
 BRCA1, BRCA2, 94, 223
 diet, 35
 ductal carcinoma *in situ* (DCIS), 108, 139, 262
 FGFR2, FGFR3, 76, 78
 gene expression profiling, 200
 genetic rearrangements, 216, 220
 hereditary, 93–94
 BRCA1, *BRCA2*, *CHEK2*, *ATM*, *BRIP1* and *PALB2*, 94
 immune signature, 135
 incidence, 1, 2, 13
 integrin-FAK signalling, 168
 invasive ductal carcinoma (IDC), 108
 metastasis, 216, 262–263
 mortality, 1–10
 obesity, 39
 oestrogen, 17, 35, 39, 41, 61–63, 169, 181, 186, 200, 217, 247, 250, 261–263, 279
 PDGF receptor, 76
 peptide vaccination, 187
 PI3K, 162
 progesterone receptor, 64
 proteomics, 197
 screening, 236
 SERMs, 182
 shift work, 40
 smoking, 33
 SNPs, 216, 224
 TGFB1, *FGFR2*, *TOX3*, *MAP3K1* and *LSP1*, 97
 staging, 243
 stem cells, 143
 survival rates
 UK, 16
 USA, 16, 189
 Burkitt's lymphoma, 200
 glossary, 280
 cachexia, 148
 glossary, 280
 cadherin genes/proteins, 127, 140, 141, 160, 166, 200, 254, 259, 312
 caesium-137, 24
 calcium, 38, 50, 59, 160, 290
 cancer antigen 125 (CA125), 230
 cancer causes, 20–43
 cancer detection
 gene expression profiling, 49, 139, 142, 178, 199–201, 225, 270
 metabolomics, 178, 200–201, 237
 protein imaging, 201
 proteomics, 196–197
 2D difference gel electrophoresis (DiGE), 196
 mass spectrometry (MALDI-TOF), 196, 289
 tumour imaging, 188–196
 ¹³C hyperpolarisation, 193–195
 computed tomography (CT), 23
 magnetic resonance imaging (MRI), 30, 190–195, 204
 optical imaging, 195–197, 202, 212
 positron emission tomography (PET), 188–193, 226, 305
 single photon-emission computed tomography (SPECT), 189
 smart contrast agents, 194
 cancer incidence, 1–8, 12, 13
 Africa, 7, 8, 10
 Australia, 2, 8, 259, 268
 Gambia, 2
 Kuwait, 2
 Malawi, 10
 Swaziland, 10, 12
 Uganda, 10
 UK, 2, 5
 USA, 2, 5
 World, 1, 5
 Zimbabwe, 10
 cancer mortality, 2–19
 Africa, 10
 Argentina, 8
 Canada, 8
 China, 9
 Colombia, 8
 Denmark, 4
 Ecuador, 8
 Europe, 4
 Finland, 4
 Hungary, 4
 India, 10
 Japan, 7–11
 Latin America, 8
 Peru, 9
 Poland, 4
 Russia, 4, 7
 Scotland, 4
 South America, 9
 UK, 2, 29, 237
 Ukraine, 4

Index

- cancer mortality (cont.)
 Uruguay, 8
 USA, 2, 5, 8, 13, 16, 27, 29
 USA Hispanic/Latino, 8
- cancer nomenclature
 prefixes and suffixes, glossary, 280
- cancer prevention, diagnosis and treatment, 178–208
- cancer regulatory signalling, 152–177
 ARF, MDM2, p53, INK4, RB1, 154–155
 BCR-ABL1, 167–168
 cadherin signalling, 165–166
 death receptors and the extrinsic pathway of apoptosis, 162–163
 DNA tumour viruses, 132
 Hedgehog signalling, 168–169
 integrin signalling, 166–167
 JAK–STAT signalling, 163–164
 MAP-kinase signalling, 51–54, 152–159
 MYC and RAS, 155–156
 phosphatidylinositol 3-kinase (PI3K), survival and apoptosis, 160–162
 senescence, 156–157
 TGF β signalling, 169–171
 VEGF and Notch signalling, 171–173
 WNT and GPCR signalling, 164–165
- cancer world patterns, 3–11
- CancerBACUP, 17, 19
- carcinogen, 28, 33, 42, 92, 230, 300, 310
 glossary, 281
- carcinoid, 256, 282, 288
- carcinoma, 29, 35, 38, 75, 77, 88, 108, 120, 132, 147
 glossary, 281
- carcinosarcoma, glossary, 281
- caretaker gene, glossary, 281
- casein kinase, 89, 165
 glossary, 281
- caspsases, 45, 113, 114, 115, 161, 162, 278
 glossary, 281
- catenin(s): β -catenin, 107, 118, 127, 160, 162, 165, 166, 254, 260
- CD (cluster of differentiation, e.g. CD8), glossary, 281
- CDC25 proteins, 56–57, 252
- cell cycle, 54–57, 80, 84–90, 98, 109, 110, 113, 152, 155–161, 169, 170, 175–176, 180, 222, 248, 266, 268
 CDK4, 99
 G₀ phase, 81
 inhibition by TGF β , 111, 170, 171
 protein degradation, 235
 tumour suppressors, 71, 93, 111
- cellular responses during tumour development, 173–174
- Cervarix[®], 187, 205, 267
- cervical cancer, 9, 10, 265–266
 incidence, 1
 smoking, 32
- characteristics of tumour cells, 102–151
 abnormal metabolism, 121–130
 how do cells sense oxygen levels? 124–125
 hypoxia-inducible factors (HIFs), 127, 135, 136, 183
 tumour blood flow 121–124
 Warburg effect, 126–130
- activation of inflammation and the immune system, 131–136
 the tumour cell environment, 132–135
- cell growth deregulation, 109–110
- induction of angiogenesis, 117–121
 angiogenic regulators, 119–121
 angiostatin, 119–121
 tumour vascularisation, 117–121
 vascular mimicry, 121
- metastasis, 136–148
 do metastases metastasise? 146
 early ideas about metastasis, 137–138
 finding the target, 142–146
 how do tumour cells become metastatic? 138–139
 metastatic footnote, 145
 primary and malignant tumours, 136–137
 stem cells, 141–142
 the epithelial to mesenchymal transition (EMT), 139–141
 resistance to cell death, 111–115
 resistance to inhibitory growth signals, 110
 unlimited replicative capacity, 115–117
- chemokine(s), 58
- chemotherapy, 81, *See also* drugs
 acute myelogenous leukaemia (AML), 180
 adoptive cell transfer (ACT) therapy, 187
 childhood acute lymphoblastic leukaemia (ALL), 180
 combination therapy, 180
 early development, 178–180
 gene therapy, 186
 kinase inhibitors, 180–181
 liposomes, 184–185
 monoclonal antibodies, 181–184
 new targets
 BRAF, 226–227
 MYC, 228–229
 P53, 229–230
 PI3K, 227–228

Index

- non-specific effects, 187–188
- targets, 178–187
- transarterial chemoembolisation (TACE), 186
- vaccines
 - peptide, 186
 - prophylactic, 186
 - therapeutic, 186
- vascular targeting agents (VTAs), 184
- Chernobyl, 24
- childhood cancers, 12, 13
 - ALL, 25, 29, 82, 180, 187, 224, 270, 292
 - SNPs, 224
 - AML, APL, 180
 - Burkitt's lymphoma, 158
 - leukaemia, 29, 30, 180, 271
 - osteosarcoma, 293
 - retinoblastoma, 87
 - rhabdomyosarcoma, 297
 - staging, 243
 - survival rate, 14
 - Wilms' tumour, 292, 301
- China, 19, 302
- cholesterol
 - membrane fluidity, 61
- choline, 193
 - glossary, 281
- chromosomal instability (CIN), 96
- chromothripsis, 218–220
 - glossary, 281
- chronic lymphocytic leukaemia (CLL), 218, 273–274
 - glossary, 282
 - SNPs, 224
- chronic myeloid leukaemia (CML), 274–275
 - glossary, 282
 - Philadelphia chromosome, 80
- circulating tumour cells, 231–232
- cis activation, glossary, 282
- clinical trials, 121, 170, 181, 183, 184, 185, 239
 - glossary, 282
- Clostridium botulinum*, 39
- Cochrane Collaboration, 39, 43, 236
- colorectal (bowel) cancer, 8, 134, 164, 166, 170, 172, 180, 183, 187, 218, 221, 224, 236, 259–260
 - alcohol, 33
 - calcium, 39
 - diet, 35
 - familial adenomatous polyposis (FAP), 95
 - glossary, 282
 - hereditary, 94–95
 - incidence, 1
 - obesity, 39
 - polypectomy, 35
 - SNPs, 224
- computed tomography (CT), 23
 - PET/SPECT-CT, 189–190
 - radiation exposure, 191
- connective tissue, 71, 105, 108, 133, 138
 - glossary, 282
- contact inhibition, 170
 - glossary, 282
- coronary artery disease, 224
- Crohn's disease, 119, 134, 224, 261
- Curie, Marie, 24
- Currie, Alastair, 112
- cyclin-dependent kinase inhibitors (CDIs), 57
 - INK4 (*inhibitor of CDK4*) A, B, C and D, 57, 155, 229
 - KIP1, 57, 157, 162
 - KIP2, 57
 - WAF1, 57, 90, 157, 162
- cyclin-dependent kinases (CDKs), 57
 - CDK4 micro RNA regulation, 99
- cyclins, 57, 157, 222
 - D, E, A and B in cell cycle, 57
- cytokeratin, 140
- cytokine(s), 44, 52, 58, 59, 111, 114, 133, 136, 144, 161, 172, 183, 234
 - cytokine receptors, 49, 58, 168
 - glossary, 282
 - granulocyte-macrophage colony stimulating factor, 58
 - interleukin 3 (IL3), 58
- Darwinism and cancer, 84, 109
- DeMars, Robert, 87
- diabetes, 39, 42, 119, 199, 224, 268
- diarrhoea
 - mortality, 3
- diet and cancer, 4, 9, 11, 16, 20, 23, 31, 35–40, 97, 199, 258, 261, 268, 269
 - balanced diet, 39
- epidemiology studies
 - European Prospective Investigation into Cancer and Nutrition (EPIC), 38
 - Nurses' Health Study, 35
 - Polyp Prevention Trial, 38
 - Wheat Bran Fiber Trial, 38

Index

- differentiation, 53, 75, 81, 98, 109, 144, 170
 de-differentiation (or retro-differentiation),
 glossary, 282
 glossary, 282
 terminal differentiation, glossary, 298
- DNA damage, 39
- DNA demethylase (TET2), 131
- DNA methylation, 92, 96, 97, 130, 260
- DNA repair, 26, 38, 68, 71, 90, 91, 93, 102, 110,
 234, 254, 281
- chromothripsis, 218, 220
- folate, 38
- HCV, 158
- radiation, 26
- DNA sequencing methods, 210–214
 heliscope single molecule sequencing, 212
 ion torrent sequencing, 213
 nanopore sequencing, 213
 next-generation or second-generation
 sequencing, 211–212
 glossary, 302
 pyrosequencing, 212
 Sanger dideoxy sequencing, 210–211
 single molecule real time sequencing, 212
 third-generation sequencing, 212
- Doll, Richard, 31, 32, 33, 39
- dominant (allele), 88
 glossary, 282
- double minute, 220
 glossary, 282
- driver mutation, 66, 68, 69, 78, 81, 90, 99, 122,
 152, 160, 171, 218–228
 chemotherapy, 233
 glossary, 283
 MYC, 91, 220, 224
- drug development, 178–186
- drug resistance, 186–188
- drugs, 17, *See also* chemotherapy
 5-fluorouracil, 180, 183, 234, 249,
 259, 266
 glossary, 284
 6-mercaptopurine, 180, 249
 glossary, 290
 6-thioguanine, 180, 249
 glossary, 298
 aminopterin, 180, 249
 glossary, 278
 anastrozole, 64, 250
- Appendix B Targets of specific anti-cancer
 drugs, 243–250
- bevacizumab (Avastin[®]), 183
- cetuximab, 180, 183, 234, 246, 261
 glossary, 281
- cisplatin, 185, 188, 248, 256, 257, 258, 259,
 260, 266
- combretastatin, 148, 185
- dasatinib, 182, 245
- doxorubicin, 185, 186, 188, 249, 260, 270
- erlotinib, 225, 245
- etoposide, 11, 188, 195, 249, 270
- figolomod, 188
- folinic acid, 180
- gemcitabine, 185, 249, 256, 258
- irinotecan, 180, 249, 258, 261
- glossary, 286
- letrozole, 64, 250
- methotrexate, 180, 187, 234, 249, 273, 278
 glossary, 291
- nilotinib, 182, 245
- olaparib, 225, 250
- oxaliplatin, 180, 248
- paclitaxel, 136, 143, 185, 235, 248, 258, 270,
 314, 316
- PLX4032 (vemurafenib), 226, 247
- prednisone, 180
 glossary, 294
- rituximab (Rituxan[®]), 183
- salinomycin, 143
- taxanes
 paclitaxel, docetaxel, 185, 248
- tocilizumab, 235
- trastuzumab (Herceptin[®]), 183, 246
- vincristine, 180, 188, 234, 248, 273
 glossary, 301
- vindesine, 188, 248
- vinorelbine, 185, 188, 256, 258
- E2F gene/protein family, 89, 155, 254
- EGFR gene/protein, 5, 44, 46, 76, 83, 126, 134,
 168, 184, 222, 234, 245, 246, 252, 257,
 263, 281
- amplification, 222
- angiogenesis, 131
- erlotinib, 225, 245
- FISH, 84
- gefitinib, 188, 245
- glioblastomas, 86
- integrins, 168
- melanoma, 221
- monoclonal antibody, 185
- mutations, 75–76, 222, 225, 231, 232, 233
- electron volt, 28, 30
 glossary, 283
- Elledge, Stephen, 234
- EMF RAPID Program, 30
- EMF Trust, 30

Index

- endocrine therapy/tissues, 64, 104
glossary, 283
- endometrial cancer, 33
obesity, 39
- endostatin, 120, 121
- endothelial cells, 60, 119, 120, 121, 127, 171,
172, 173, 185
endothelial cell/endothelium, glossary, 112,
118–122, 127, 283
MCT expression, 128
S1PR1 expression, 61
tumour microenvironment, 133
- enhancer, glossary, 283
- enhanson, glossary, 283
- enzyme-coupled receptors, 44–49
- epidemiology, 1–19
meta-analysis, 39
study design, 36
- epidermal growth factor (EGF), 47, 53, 58, 75
- epigenetics, 96–97, 231
CpG islands, 98
- epithelial cell, 52, 108, 112, 134, 136, 140, 143,
166, 170, 231
glossary, 283
- Epstein–Barr virus, 158
glossary, 283
- ERBB2* gene/protein, 50, 228, 234, 261, 263, 279
Herceptin[®] (trastuzumab) monoclonal
antibody, 183
mutations, 182, 222
orphan receptor, 48
- ERBB2* protein, 48, 222, 263, 269
lapatinib, 182
- ERK1 transcription factor, 51, 167, 176
- ETV6* and *RUNX1* genes/proteins, 81–83, 85
childhood ALL, 82
- euchromatin, glossary, 283
- Ewing's sarcoma
EWS-ETS gene, 69
glossary, 284
- expressed sequence tag (EST), glossary, 284
- expression vector, glossary, 284
- extracellular matrix, 133, 166, 174, 185, 230
glossary, 284
- familial medullary thyroid carcinoma (FMTC),
glossary, 284
- Fanconi anaemia, 94
- Farber, Sidney, 180
- fatty acid, 61, 125, 249
glossary, 284
- FBXW7* gene/protein, 70
- fibre, 38–39
- fibroblast growth factor receptor (FGFR) family
genes/proteins, 46, 76, 78, 107, 142,
222, 224, 263
- fibronectin, 144, 145, 167, 279, 300
- fibrosarcoma, glossary, 284
- fluorescence *in situ* hybridisation (FISH), 82,
84, 220
glossary, 284
- fluorodeoxyglucose (FDG), 189–190
- focal adhesion kinase (FAK), 163, 167
- folate, 37–38, 179, 267, 277
- folinic acid, 180
glossary, 284
- Folkman, Judah, 121
- follicular lymphoma, 161
SNPs, 224
- fullerene, 202
glossary, 284
- G-protein-coupled receptors (GPCRs), 59
intracellular signalling, 59, 66, 161, 165, 169
trimer G proteins, 59
- gain-of-function mutation, 67, 129, 166
glossary, 284
- gallbladder cancer, 8
obesity, 39
- gamma rays, 24
- Gardasil[®], 187, 205, 266, 267
- gatekeeper gene, glossary, 284
- gene deletion, 66, 71, 72, 75, 81–84, 98, 161,
162, 181–183, 216, 222
- genetic instability, 70, 71, 90, 93, 94, 95, 96, 110,
158, 166, 218, 234
glossary, 284
- genome-wide association (GWA) studies, 223–225
- genomic partitioning, 220–223
- germ line mutation, 24, 224, 295
- glioblastoma multiforme, 183
glossary, 285
- glioma, 30, 31, 218, 224
glossary, 285
- glucose transporters, 126, 128
- glycolysis, 122–127
- glycosaminoglycan, glossary, 285
- glycosylphosphatidylinositol (GPI), 166
glossary, 285
- granulocyte-macrophage colony stimulating
factor (GM-CSF)
glossary, 285
- graphene, 202
- GRB2 protein, 48, 51, 161, 167, 168
- green fluorescent protein (GFP), 146
glossary, 285

Index

- growth factor, 44, 47, 54, 58, 71, 75, 107, 111, 137, 144, 163, 235
glossary, 285
- hairy cell leukaemia, 270
glossary, 285
- Haldane, J. B. S., 117, 236
- half-life, 23, 24, 26, 58, 85, 126, 183
glossary, 285
- haploinsufficiency, 163
glossary, 285
- haplotype, 224
glossary, 285
- heart disease
mortality, 3
- Hedgehog signalling, 45, 142, 168–169, 169, 223, 247
- Helicobacter pylori*, 21, 132
- hemangioblastoma, glossary, 285
- hepatocellular carcinoma (HCC), 132, 135
See also liver cancer
- heterocyclic amines and polycyclic aromatic hydrocarbons, glossary, 285
- heterozygosity, 220
glossary, 285
- high-frequency magnetic fields (mobile phones), 30–31
- Hill, Austin Bradford, 31
- Hiroshima and Nagasaki, 24
- Hirschsprung's disease, glossary, 285
- histone deacetylase, 63, 128, 251
glossary, 285
- HIV
glossary, 286
- HIV/AIDS
epidemic, 12
glossary, 277
Kaposi's sarcoma, 10
mortality, 3
immune system, 71
telomerase, 118
- Hodgkin's lymphoma, 108, 180, 187, 190
glossary, 286
- how does cancer kill you? 146–147
- hypoxia, 118, 122–128
cycling, 122, 136
glossary, 286
- hypoxia-inducible factors (HIFs), 124–128, 136, 184
- immune system, 21, 40, 44, 58, 71, 131, 131–136, 145, 148, 164, 183, 186, 188
adaptive, 108
glossary, 286
- immunoediting, 136
- immunoliposomes, 183
- immunotherapy, 182, 187
- infection, 10, 11, 14, 21–22, 34, 70, 71, 107, 147, 178, 185, 257–276
- inflammation, 21, 112
immune system, 131–136
tobacco smoke, 32
- inhibitor of apoptosis proteins (IAPs), 115
- initiation site, glossary, 286
- inositol 1,4,5-trisphosphate (IP₃), 50, 59, 60
glossary, 286
- insertional mutagenesis, glossary, 286
- insulin, 40, 46, 137, 281
insulin receptor substrate (IRS), 49
insulin-like growth factor receptor type 1 (IGF1R), 245
insulin-like growth factor-binding protein, 170
insulin-like growth factors (IGFs), 61, 174
receptors, 46, 49, 300
- integrins, 49, 145, 161, 166, 167, 168, 173, 176, 184, 195
signalling, 166–167
- interferon(s), 59, 132, 134, 136, 164, 183
- interleukin(s), 58, 59, 133, 134, 135, 144, 164, 183, 247
- International Agency for Research on Cancer (IARC), 31
- Interphone Study Group, 31, 43
- iodine-131, 24
- ionising radiation, 22–26
- isocitrate dehydrogenase (IDH1/2), 129, 274
- Jain, Rakesh, 146
- Janus kinases (JAKs), 58, 159, 163–164, 168
- Kaposi's sarcoma, 10, 12, 71, 183, 185, 277, 287
- karyotype, glossary, 287
- Kerr, John, 112
- kidney cancer, *See* renal cell carcinoma
- KIT* gene/protein, 46, 76, 107, 182, 188, 234, 245, 246, 248, 252, 274, 300
- Knudson, Alfred, 87
- lactate, 123, 125, 127
transporters
MCT1, MCT4, 128, 129
- landscaper gene, 69
glossary, 287
- Lane, David, 89
- large cell neuroendocrine carcinoma, 257

Index

- leucine zipper, 55
 - glossary, 287
- leucocyte, 108
 - glossary, 287
- leukaemia, 9, 108, 269–275
 - childhood leukaemia, 29, 30, 180, 271
 - glossary, 287
 - mortality, 2
 - radiation, 24
- leukaemia initiating cells (LIC), 82
- leukosis, glossary, 287
- Lickint, Fritz, 32, 33, 303
- life-style, 13
- ligand stromal-derived-factor-1 (SDF1)
 - detection by CXCR4, 61
- ligand-gated ion channels
 - receptors, 60
 - superfamilies, 60
- linkage disequilibrium, glossary, 287
- liver cancer, 9, 10, 258–259
 - alcohol, 33
 - hepatocellular carcinoma (HCC), 132, 135
 - mortality, 3
 - obesity, 39
 - smoking, 32
- lod score (Z), glossary, 288
- long control region (LCR), glossary, 287
- long terminal repeat (LTR), glossary, 288
- loss of (constitutional) heterozygosity (LOH/LOCH), glossary, 288
- loss-of-function mutation, 50, 71, 74, 87, 153, 155, 157, 235
 - glossary, 288
- low-frequency magnetic fields, 29–30
 - childhood leukaemia, 29
- lung cancer, 21, 254–257
 - alcohol, 33
 - glossary, 288
 - incidence, 1
 - mortality, 3, 7, 8, 9
 - non-small cell lung cancer, 163, 187, 218, 225, 233, 235, 255, 288, 291
 - small cell lung cancer, 216, 218, 255, 288
 - smoking, 31–33
 - SNPs, 224
 - staging, 243
 - survival rate, 14
- Lyden, David, 145
- lymphocyte, 108
 - glossary, 288
- lymphoid cell/tissue, glossary, 288
- lymphokine(s), 58
- lymphoma, 79, 94, 108, 132, 133, 161, 195, 204
 - diffuse large-B-cell lymphoma, 200
 - follicular lymphoma, 224
 - glossary, 288
 - see also Burkitt's lymphoma; Hodgkin's lymphoma; non-Hodgkin's lymphoma 288
- macrophage, 133, 135, 136, 183, 206
 - glossary, 289
- major histocompatibility complex (MHC), glossary, 291
- malaria
 - mortality, 3
- MALDI-TOF, 196
 - glossary, 289
- malignant tumour, 136–146
 - glossary, 289
- MAP-kinase signalling, 44, 45, 51–54, 143, 152–159, 166, 168, 171, 226–227, 235, 263
 - glossary, 289
- Marfan's syndrome, glossary, 289
- mass spectrometry (MS), 196, 197
 - glossary, 290
- mast cell, 133
 - glossary, 290
- matrix metalloproteinases (MMPs), 119, 145, 167
 - inhibition, 185
 - transcription, 172
- MAX protein
 - MAX-MYC transcription factor, 55
 - MLX, MXI1, MNT and MXD family interaction, 56
- melanocyte, 28, 54, 104, 132, 290, 292
 - melanin, 28, 104
- melanoma, 28, 29, 41, 183, 192, 214, 221, 226, 227, 238, 290, 291, 310, 311, 317, 318, 319
 - BRAF mutation, 107, 214, 226
 - cell transfer, 131
 - chromothripsis, 218
 - drug resistance, 187
 - glossary, 290
 - integrins, BCAR1, CRK, ILK, 168
 - malignant melanoma, 28, 29, 107, 224
 - metastasis, 184
 - metastasis suppressor genes, 144
 - mortality, 4
 - mutation, 221
 - mutations
 - BRAF, NRAS, 227
 - ERBB4, 221
 - naevi, 106

Index

- melanoma (cont.)
 NRAS, BRAF, MAPKK, 54
 organ transplants, 131
 osteopontin, 170
 RET, 132
 SNPs, 224
 surgery, 29, 131
 treatment, 214
 5-fluorouracil, 183
 adoptive cell transfer, 187
 IL2, interferon, 183
 tyrosine kinase, 221
 MEN 1/MEN 2A/MEN 2B, glossary, 290
 meningioma, 31, 105
 glossary, 290
 merlin (NF2), 106
 mesenchymal cell, 108, 140, 171
 glossary, 290
 mesothelioma, 256
 glossary, 291
 metabolism and cancer, 29, 67, 121–130, 158,
 189, 192, 194
 major metabolic pathways, 124
 metastasis, 71, 84, 136–146, 171, 174, 184,
 220, 224
 angiogenesis, 121
 FAK signalling, 168
 genomic sequencing, 216
 glossary, 291
 LKB1, 163
 macrophages, 136
 metastatic efficiency, 146
 miRNAs, 98
 MMPs, 185
 prolyl hydroxylase, 127
 RAS proteins, 53
 suppressor genes/proteins, 144, 167
 targeting, 61, 144, 145
 TGF β , 172
 metastasis suppressor genes/proteins, glossary,
 291
 metastatic signature/genes, 144
 glossary, 291
 VEGF, *COX2*, *EGFR*, *MMPs*, 135
 micro RNAs (miRNAs), 97–99, 300, 313
 micro/minisatellite (repetitive) DNA, 96
 glossary, 291
 microsatellite instability (MIN), 96
 minimal inverted repeat, glossary, 291
 mismatch repair genes/proteins, 93, 224, 254
 mitogen(s), 44, 45, 51, 52, 54, 64, 144, 315
 glossary, 291
 modifier gene, glossary, 291
 moles, birthmarks, 104
 monoclonal antibody, 122, 164, 178, 181–184,
 204, 246, 273, 274, 282
 glossary, 292
 monocyte, glossary, 292
 multiple myeloma (myelomatosis), 187, 235
 glossary, 292
 mutation signatures, 109
 mutation(s), 1, 13, 22, 29, 32, 51–58, 105–110,
 116, 127–130, 132, 138–147, 152–155,
 160–176, 181, 186, 214, 238
 driver, 67, 69, 79, 82, 84, 91, 100, 148, 150,
 220, 226, 228, 233
 in cancer development, 66–99
 passenger, 69, 161, 220, 224
 rate of accumulation, 13, 67–69
 mutator phenotype, 96
 MYC gene/protein, 15, 64, 66, 73, 79, 150, 154,
 165, 178, 224, 240, 253, 257, 261, 263,
 272, 281
 amplification, 58, 75–78
 colon cancer, 222
 apoptosis, 90
 Burkitt's lymphoma, 86
 cell proliferation, 54–58, 89
 cellular abundance, 78
 chromothripsis, 220
 control of expression, 56
 DNA replication, 56
 double minute chromosomes, 220
 driver, 91
 family, 55
 inhibition by Omomyc, 56, 228
 metabolic regulation, 123
 mutations, 79, 231
 oncogene addiction, 156
 oncogenic signalling, 155, 156, 157
 proliferation, 90, 133
 pyruvate kinase, 127
 regulation by MAX, 56, 228
 regulation by β -catenin, 166
 repression, 111
 small molecule inhibitors, 229
 stem cell signature, 143
 TGF β , 171
 therapeutic targeting, 228–229
 translocation, 84
 tumour suppression, 157
 ubiquitination, 58
 myeloblast, glossary, 292
 myelocyte, myelocytomatosis, glossary, 292
 myeloid cell/tissue, 77
 glossary, 292

Index

- myoblast, glossary, 292
- myofibroblast, glossary, 292
- nanocells, nanotubes, nanoparticles (SPIONs), 195, 202, 204
- natural killer (NK) cell, 40, 183, 288
glossary, 292
- neoplasm, 89, 103, 104, 108, 113, 132
glossary, 292
- nerve growth factor (NGF), 53
glossary, 292
- neural cell adhesion molecule (NCAM),
glossary, 292
- neural crest, glossary, 292
- neuroblastoma, 76, 79
glossary, 292
SNPs, 224
- neurofibromatosis Type 1 (Von Recklinghausen's
disease or multiple neuroma),
glossary, 292
- neurofibromin (NF1), 106
- neutron, 22, 24
- next-generation or second-generation
sequencing, 209, 211–212
glossary, 292
- NM23* gene/protein, 144,
- N-methyl-N'-nitrosoguanidine (MNNG),
glossary, 291
- NMYC* gene/protein, 77
- non-Hodgkin's lymphoma, 72, 86, 108, 183,
189, 190
glossary, 292
mortality, 2
- Notch signalling, 119, 142, 171–173
- nuclear factor κ B (NF- κ B), 133, 135, 185
glossary, 292
- obesity, 39–40
- oesophageal cancer, 9, 10, 263–265
alcohol, 33
obesity, 39
smoking, 32
- oncogene addiction, 156, 234
glossary, 293
- oncogenes, 66, 69–73, 87, 95, 113, 126, 131, 156,
172, 225, 234
first human oncogene, 71–72
glossary, 293
proto-oncogene to oncogene, 72–85
proto-oncogenes, 70
- open reading frame (ORF), glossary, 293
- oral cancers
alcohol, 33
coffee drinking, 35
nasopharyngeal cancer, 9
smoking, 32
- ornithine decarboxylase, 55
glossary, 293
- osteosarcoma, 131
glossary, 293
- ovarian cancer, 10
alcohol, 33
obesity, 39
SNPs, 224
- oxaliplatin, 180, 248
glossary, 293
- P53 (TP53)* gene/protein, 88–92
BAX, *PUMA* and *NOXA*, 90, 114, 160, 162
cancer driver, 70
DNA damage, 89, 113, 118
gene therapy, 186
Li-Fraumeni syndrome, 92, 262
metabolism, 125, 128
micro RNA, 99
mutations, 92
p53 family (p63, p76), 91, 93
p53 in cell cycle, 57, 111
p53 DNA structure, 92
tetramer, 92
therapeutic targeting, 229–230
- pancreatic cancer, 267
obesity, 39
smoking, 32
SNPs, 224
- papilloma, glossary, 293
- passenger mutation, 69, 161, 220, 224
glossary, 293
- passive smoking, 32
- Peto, Richard, 39, 302
- phaeochromocytoma, 105
glossary, 293
- Philadelphia chromosome
chronic myeloid leukaemia (CML), 80, 271,
272, 275
- phosphatidylinositol, 50, 59, 61, 161, 173
glossary, 293
- phosphatidylinositol 3-kinases (PI 3-kinases or
PI3Ks), 58, 160–164, 177, 181, 222,
223, 226, 234, 235, 247
glossary, 293
inhibition, 185
integrin signalling, 167
PIK3CA subunit cancer driver, 70, 107, 227,
257, 268
proliferation and apoptosis, 156

Index

- phosphatidylinositol 4,5-bisphosphate (PIP₂), 59
- phosphatidylserine, 112, 194
glossary, 293
- phosphoinositide, 49
glossary, 294
- phospholipases
phosphatidylinositol-specific phospholipase
C γ (PLCG1), 48, 50, 159, 161
- phospholipase C β , 59, 166
- phosphorylation, 47, 49, 50–56, 127, 160, 168,
181, 188, 226, 235
glossary, 294
- phosphoproteome, 196
- phosphotyrosine binding (PTB) domains, 49
- plasmacytoma, glossary, 294
- plasmid, glossary, 294
- platelet, 146, 150
glossary, 294
- platelet derived growth factor (PDGF), 294
breast cancer, 76
glossary, 293
receptors, 46, 226, 234
amplification, 76, 84
angiogenesis, 174
inhibition, 182, 245
translocation, 86
- PML-RARA* gene/protein, 79–81, 157
- polymorphonuclear leucocyte (granulocyte),
glossary, 294
- positron emission tomography (PET), 129,
188–193, 226, 305
glossary, 293
single photon-emission computed tomography
(SPECT), 189
- potassium, 22, 23, 143
- prolyl hydroxylase (PHD), 126, 184
- promoter (transcription), 85, 93, 98, 99, 127,
162, 196
glossary, 294
- prostaglandin receptor, 61
- prostate cancer, 10, 268–269
alcohol, 33
androgens, 64
Hedgehog signalling, 170
hormone treatment, 180
imaging, 195
incidence, 1, 13
metastasis, 195
mortality, 4, 8, 9, 14
sipuleucel-T (Provenge[®]), 186
smoking, 33
SNPs, 224
staging, 243
survival, 189
treatment
5-fluorouracil, 183
WNT signalling, 165
- prostate specific antigen (PSA), 230
- protein kinase A (PKA), 59, 173, 248
- provirus, integration, tagging, glossary, 294
- pseudogene, glossary, 295
- pyruvate kinase, 123
isozymes, 127
- radiation, 21–31
exposures from medical sources, 23
- radical (free radical), 28, 29, 68
glossary, 295
- radioimmunotherapy, 183
- radium, 24, 26
- radon, 26–27
- RAF1* gene/protein, 51, 52, 53, 182, 226, 227,
234, 245, 289
- RAS genes/proteins
KRAS2, 70, 73, 96, 228, 231, 267
mutation, 73–74
- RAS superfamily, 52, 53
CDC42, 53, 159, 160, 176
- RAB, 53
- RAC, 53, 61, 173, 176
- RAD/GEM, 53
- RAN, 53
- RHO, 53, 61, 173
- signalling, 51–58
- reactive oxygen species (ROS), 67, 118, 127
glossary, 295
scavengers
vitamin C, α -tocopherol, 68
- real time PCR, glossary, 295
- receptor guanylyl cyclases, 47
- receptor serine/threonine kinases, 45, 47
- receptor tyrosine kinases (RTKs), 45, 52, 65,
228, 319
amplification, 84
EGFR, 75
family, 76
GPCR pathways, 61
kinase, glossary, 300
scaffolds, 159
signalling, 45–58
tyrosine kinase, glossary, 300
- recessive gene, 88
- recombination, 117, 288
homologous, 93
glossary, 286
- renal cell carcinoma (RCC)

Index

- glossary, 295
- mTOR, 163
- obesity, 39
- smoking, 32
- retinoblastoma, *RB1* gene/protein, 85, 86–88, 229, 259, 266
 - E2F interaction, 89
 - glossary, 295
 - in cell cycle, 57, 86–88, 110
- retinoic acid
 - all-*trans* retinoic acid (ATRA), 80
 - glossary, 295
- reverse transcriptase, 118
 - glossary, 297
- rhabdomyosarcoma, glossary, 297
- rheumatoid arthritis, 119, 224, 235
- RNA editing, 216
 - glossary, 297
- Rous sarcoma virus, 71

- Sanger dideoxy sequencing, 210–211
- sarcoma, 71, 108
 - glossary, 297
- scaffold protein(s), 49, 54, 64, 140, 159, 167, 168, 177, 227, 297
 - glossary, 297
- schwannoma, 106
 - glossary, 297
- screening programmes, 9, 13, 14, 18, 231, 233, 236–237
- selective oestrogen receptor modulator (SERM), 64, 182
 - tamoxifen, 64, 171, 181, 247, 251
- senescence, 80, 90, 116, 154, 156–157, 159, 175, 229
 - glossary, 297
- serine/threonine kinase protein kinase C (PKC), 60
 - isozymes, 60, 90, 163, 166, 248
 - PKC α , 163
- SH1 tyrosine kinase domain, 49
- SH2/SH3 domains, 48, 49, 50, 51, 65
- single nucleus sequencing, 84
 - glossary, 297
- single-nucleotide polymorphisms (SNPs), 95, 96, 215, 220, 224
 - glossary, 297
- small interfering RNA (siRNA), 204, 235, 297
- smoking and tobacco, 8, 9, 31–33
 - Africa
 - mortality, 32
 - DNA adducts, 68
 - WHO control convention, 7
- Snail, 140
- SOS protein, 51, 75, 161
- Southern blot, glossary, 297
- sphingosine 1-phosphate, 61, 173, 188
 - glossary, 297
- splice acceptor site (SA), glossary, 298
- splice donor site (SD), glossary, 298
- squamous carcinoma, 29
 - glossary, 298
- SRC* gene/protein, 74–79, 127, 158, 162, 167, 245, 246, 247
 - protein domains, 49
 - Rous sarcoma virus (retrovirus), 71
 - tyrosine kinase, 58, 71
- STATs (signal transduction and activator of transcription) proteins, 58, 133
- stem cells, 81, 82, 115, 117, 140–142, 150, 158, 242, 273, 275, 282, 285, 288, 290, 292, 299, 310
 - leukaemia, 81–82
 - mutation, 141
 - surface markers, 141
 - telomerase, 116, 118
- steroid hormones, 40, 44, 60–63, 167
 - androgen family
 - testosterone, 61, 62, 251, 270
 - cortisol, 40, 42, 61
 - oestrogen, 17, 35, 40, 41, 61, 62, 63, 64, 170, 182, 187, 200, 205, 206, 247, 251, 262, 279
 - progesterone, 61, 62, 63, 64, 246, 263, 279
 - steroid hormone receptors, 62
 - tamoxifen, 64, 171, 181, 186, 247, 250
 - cytochrome P450, 64
- stomach (gastric) cancer, 9, 10, 257–258
 - alcohol, 33
 - glossary, 298
 - incidence, 1
 - mortality, 3
 - smoking, 32
- stress, 40
 - cortisol, 40, 61
- stroma, 61, 133, 136, 141, 146, 172
 - glossary, 298
- strontium-90, 25
- superparamagnetic iron oxide nanoparticles (SPIONs), 195
- synthetic lethality, 185, 225
 - glossary, 298
- systems biology, 64, 174–175, 222

Index

- tea and coffee, 35
- telomeres/telomerase, 115–117, 149, 156, 160, 284, 297
 glossary, 298
 oncogenic signal, 157
- teratoma, teratocarcinoma, 106
 glossary, 298
- testicular cancer, 14, 204
 chemotherapy, 180
 SNPs, 224
- therapeutic strategies, 15, 179, 186, 200, 224–238
- thrombospondin, 131
- thyroid cancer, 25, 104, 147, 166, 218
 SNPs, 224
- thyroid hormones
 glossary, 298
 receptors, 62, 166
- thyroxine, 25
- tracheal cancer, 257
- trans*-activation, glossary, 298
- transcription factor, 51, 55, 56, 58, 61, 77, 80, 88, 90, 92, 93, 125, 133, 140, 143, 156, 161, 167, 169, 171, 176, 224, 228
 glossary, 299
- transcriptome, 136, 199, 216
 glossary, 299
- transduction, glossary, 299
- transfection, 72
 glossary, 299
- transformation, 71, 170
 glossary, 299
- transforming growth factors (TGFs)
 glossary, 299
 TGF β , 111, 169–171, 234, 294
 angiogenesis, 135
 bone matrix, 144
 EMT, 150
 metastatic switch, 111
 signalling disruption, 216
 TGF α , 61
- transgenic organism, 83, 89, 95, 131, 136, 157, 229
 glossary, 299
- transposons, glossary, 299
- trends in cancer, 11
- tricarboxylic acid cycle (TCA cycle), 123
- TRKA* gene/protein, 53, 246
- tropical spastic paraparesis (TSP), glossary, 300
- tuberculosis, 21, 188
 mortality, 3
- tumour biomarkers, 178, 197, 199, 214, 225, 230–231, 237
 cancer antigen 125 (CA125), 230
 prostate specific antigen (PSA), 230
- tumour grading and staging
 Appendix A, 241–244
- tumour necrosis factor receptor (TNFR), 45, 115, 163
- tumour necrosis factor- α (TNF α), 45, 132, 133, 160
- tumour promoter, 32, 111, 300
 glossary, 300
 tetradecanoyl phorbol acetate (TPA), 133
- tumour suppressor genes, 66, 79, 84–92, 94, 98, 109–112, 125, 127, 132, 153–162, 165, 169–171, 185, 220, 222, 225, 227, 229, 234, 252, 266, 311
 defined, 71
 glossary, 300
- Twist, 140
- two-hit model, 87
- tyrosine kinase, 49, 58, 71, 80, 167, 168, 221 *See also* receptor tyrosine kinases (RTKs)
- tyrosine phosphatases, 46, 47, 48, 50, 304
- ubiquitin-proteasome pathway, 57, 80, 125, 154, 161, 235
 glossary, 300
- UK
 cancer incidence, 2, 13, 29, 214
 cancer mortality, 2–9, 13–17, 29, 237
 childhood leukaemia, 29
 smokers, 32
- ultraviolet (UV) radiation, 22, 28–29, 41, 67, 89, 90, 93
- uniqueness of malignancy, 137
- USA
 cancer incidence, 2
 cancer mortality, 1–9, 11, 13, 16, 27, 29
 Hispanic/Latino, 8
 childhood leukaemia, 29
 CT scans, 23, 191
 diabetes, 39
 screening, 236
 smoking and cancer, 31
- vascular endothelial growth factor (VEGF), 119, 127, 135, 144, 171–173, 229, 234, 249, 313
 inhibition, 120, 121, 181–183, 245
 signalling, 171–173
- Venter, Craig, 215
- verrucae (*verruca plantaris*), 106
- VHL* (von Hippel–Lindau) gene/protein, 126, 185
 glossary, 301

Cambridge University Press

978-1-107-01398-8 - Introduction to Cancer Biology: A Concise Journey from Epidemiology through Cell and Molecular Biology to Treatment and Prospects

Robin Hesketh

Index

[More information](#)

335

Index

- vimentin, 140, 141
- viruses
 - adenovirus, 186
 - DNA tumour viruses, 89
 - hepatitis B virus (HBV), 10, 14, 158, 259
 - vaccine, 11, 187
 - hepatitis C virus (HCV), 14, 157, 258
 - vaccine, 11
 - human papillomavirus (HPV), 10, 14, 106, 158, 265
 - vaccine, 11, 186, 187
 - RNA viruses (retroviruses)
 - glossary, 307–309
 - human T cell lymphotropic virus (HTLV), 72
 - glossary, 286
 - life cycle, glossary, 295
 - vector, glossary, 296
- vitamin D, 28, 61, 62
- Warburg, Otto, 123
 - Warburg effect/aerobic glycolysis, 123, 126–130
 - wasting disease, 109
- warts, 104
- Watson, James, 215
- WEE1 protein, 57
- Werner syndrome, 94
- whole genome sequencing and cancer, 209–225
- Wilms' tumour (nephroblastoma),
 - glossary, 301
- WNT signalling, 118, 142, 161, 164–165, 223, 291
- World Cancer Research Fund, 39, 42
- Wyllie, Andrew, 112
- X chromosome inactivation, 97
- xenotropic, glossary, 301
- X-rays, 21, 29, 67
 - imaging, 12, 27, 189, 190
 - medical, 22, 23