

## Index

### A

Abiona, Olubukola, 77  
Acuitas Therapeutics, 43, 52, 54, 73, 81,  
92–93, 95–96  
adenine (A)  
in DNA, 6, 101  
in RNA, 6, 36, 40, 54, 65,  
80–81, 102  
Afeyan, Noubar, 56, 58, 59, 62  
Alexion, 62  
Alnylam Pharmaceuticals, 43, 60, 63, 94,  
95, 98  
alphavirus, 69, 91  
Amgen, 7, 27  
amyloidosis, transthyretin (ATTR), 95  
Anderson, Dan, 92  
antibodies, 4, 22, 85–86  
in AIDS, 29, 66  
in cancer, 85–86, 87, 88, 98  
in cytomegalovirus infection, 72  
definition of, 101  
in flu, 24, 26, 66  
monoclonal, xiii–xiv, 50, 84, 85–86, 98  
and spike protein, 77, 78, 80  
antigens, 22, 29, 30, 80, 101  
and neoantigens, 85, 86, 87  
Arbutus, 63, 95  
Arcturus, 89, 91, 97  
Astellas, 86  
AstraZeneca, 62, 65, 72, 73, 74, 75, 99  
ATTR (transthyretin amyloidosis), 95  
autoimmune diseases, xiii, 2, 88

### B

Baltimore, David, 12  
Bancel, Stéphane, 55–56, 59–61,  
63–65, 67  
Barnathan, Elliot, 38, 39

Bayh–Dole Act, 41  
B cells, 22, 40  
Berkley, Seth, 66  
Bethesda Research Lab, 18  
Bill & Melinda Gates Foundation, 52, 66  
BIO biotech lobbying group, 71  
Biogen, 7, 27  
Biomedical Research and Development  
Authority (BARDA), 66, 73  
bioMérieux, 26, 55, 56, 59, 60  
BioNTech, x, xi, 54, 63, 79–88  
cancer research, 77, 79, 80, 84, 86–88  
collaboration with Pfizer, 82–84  
(*see also* Pfizer-BioNTech vaccines)  
and CureVac vaccine approach com-  
pared, 53  
dosage of COVID-19 vaccine, 52, 81, 91  
efficacy of COVID-19 vaccine, 52, 81  
flu vaccine, 82, 96  
industrial RNA production, 97  
Karikó at, 44  
lipids used by, 15, 52, 93, 94, 95, 96  
in Operation Warp Speed, 72, 73, 74,  
75, 76  
principle behind COVID-19 vaccine  
of, 10  
pseudo-uridine in COVID-19 vaccine  
of, 73, 80–81  
Şahin at, 44, 74, 79–87  
bioterrorism, 52, 66  
bird flu virus, 69, 70, 98  
Birx, Deborah, 73  
Bloom, Floyd, 39  
BNT162b2 vaccine, 80  
Bourla, Albert, 82, 83  
Bowers, Albert, 16  
Brenner, Sydney, 6, 13  
Broad Institute, 59

## 110 Index

Brookhaven National Laboratory, 14  
Bush, George W., 57

### C

calcium phosphate, 14  
Calder, Alexander, 2  
Canadian Liposome Company, 93  
cancer, xiii, 2, 11, 85–88  
    BioNTech research on, 77, 79, 80, 84, 86–88  
    CureVac research on, 50, 51, 53  
    lipids as therapy vectors in, 93  
    Moderna research on, 64, 65, 84  
    Pascolo research on, 50  
    personalized treatment in, 99  
    Pfizer research on, 84  
    Rammensee research on, 46, 47  
    self-amplifying RNA in, 98  
    targeting of therapy in, 98  
    T cells in, 45, 46  
Carresco, Luis, 37  
Cech, Tom, 5, 6, 7  
Cellsript, 42, 81  
Centogene, 65  
Centokor, 39  
CFTR mutations in cystic fibrosis, 97  
Chambon, Pierre, 28  
Chien, Ken, 58, 62  
Chikungunya virus, 66, 97  
Chiron, 11, 26, 27, 70  
chromosomal DNA, 13  
Clements-Mann, Mary Lou, 26  
Cochin Hospital and Institute, 28, 29, 32, 48  
codons, 6, 12–13, 51, 54, 101  
Cold Spring Harbor Laboratory, 91  
Collins, Francis, 73  
Corbett, Kizzmekia, 77  
coronavirus, 77  
    genomic sequence of, x, 1, 67, 80  
    in Middle East respiratory syndrome, 78  
    spike protein of (*see* spike protein of coronavirus)  
    variants of, 89  
COVID-19 pandemic, x, xii, 44, 79–80

COVID-19 vaccines, x–xi, xiii, 7, 10  
    of Arcturus, 91  
    of BioNTech, 52, 53, 81 (*see also* BioNTech)  
    of CureVac, 50, 51, 52, 53  
    dosage in, 52, 53, 73, 81, 91  
    effectiveness of, x, 52, 75, 76, 80, 81, 89  
    emergency use authorization of, 76  
    lipids in, 95–96 (*see also* lipids and liposomes)  
    mail carrier metaphor on, 3–4  
    Malone on, 9, 23–24  
    of Moderna, 10, 15, 35, 52, 55, 64, 66 (*see also* Moderna)  
    profits from, 79, 83, 87  
    pseudo-uridine in, 73, 80–81  
    speed in development of, x, 1, 69–78  
Crick, Francis, 5, 12  
Crucell, 17, 63  
Cullis, Pieter, 42–43, 92–96, 98  
CureVac, 47–54, 63, 81  
    lipids used by, 52, 73, 93, 95  
cystic fibrosis, xiii, 2, 39, 65, 96–97  
cytokines, 3  
cytomegalovirus vaccine, 66–67, 72  
cytosine (C), 36, 40, 65  
    codon sequence of, 6, 54, 80–81, 102  
    in DNA, 6, 101  
    and GC enrichment methods, 51, 54, 81

### D

Dahl, Gary, 42  
Darnell, James, 5  
DEAE-dextran, 14  
Defense Advanced Research Projects Agency (DARPA), 52, 66, 73  
Defense Production Act, 76  
de Hofmann, Frederic, 17  
dendritic cells, 38, 42, 46  
DeRosa, Frank, 96–97, 98  
Dimitriadis, Giorgos, 10, 14  
DNA, 5, 7, 12, 13  
    and cancer, 85  
    and cationic liposomes, 14–15, 16, 21  
    definition of, 101  
    and gene therapy, 17–18, 28, 30, 42, 94, 97

- naked, 21–23, 25, 26
- in plasmids, 13, 36–37, 61
- production methods, 13, 25
- and proteins, 2, 6, 13, 21–22, 29–30, 59
- research focus on, 4, 7, 14, 19, 20, 32, 91
- and retroviruses, 11, 12
- and Semliki virus, 90
- stability of, 7, 11, 19, 20, 25
- DNA vaccines, 22–23, 47, 91
  - flu, 24–26, 30
  - in Operation Warp Speed, 72, 74, 75
  - safety of, 26, 30–31, 47, 74
- Donnelly, John, 25
- Dormitzer, Phil, 70
- Dunn, John, 14
- E**
- Ebola virus, 70, 72, 91, 97
- Edmonds, Mary, 6
- electroporation, 92
- Eli Lilly and Company, 59
- Epstein, Jonathan, 99
- erythropoietin, 42, 60, 61
- European Journal of Immunology*, 32, 46
- European Union, 28, 48
- F**
- Fauci, Anthony, 38, 73
- Felgner, Philip, 9, 16, 20–22, 23, 39, 40, 90
  - lipids in research of, 10, 14–15, 18, 20, 21, 31, 38
  - muscle protein production in research of, 21–22, 25, 29
  - on safety of naked DNA vaccines, 26
- fibroblast activation protein (FAP), 99
- Fire, Andrew, 94
- Fixvac, 87
- Flagship Ventures, 56, 58, 59, 60
- flu vaccines, xiii, 24–26, 30, 44, 52
  - H1N1 strain, 70
  - Moderna research on, 64–65, 66
  - of Pfizer and BioNTech, 82, 96
- Food and Drug Administration, 26, 62, 73, 75, 83, 95
- Fosun, 83
- F protein of RSV, 77, 78
- France, mRNA research in, 27–33
- Francia, Zsuzsanna, 44
- Friedman, Theodore, 12, 21
- frog embryo research of Malone, 17, 18, 21
- G**
- Ganymed Pharmaceuticals, 86
- Garcia, Pablo, 13, 14
- Gardosil, 82
- Gates, Bill, 3
- Gavi, the Vaccine Alliance, 66
- Geall, Andrew, 69, 70, 98
- Gelsinger, Jesse, 94
- Genentech, 7, 11, 27, 62
- gene therapy, 12, 17–18, 20–21, 28, 30, 42, 94, 97
- genetic engineering, 7, 11, 15, 28, 84
- genomic sequence, 28
  - in coronavirus, x, 1, 67, 80
- Genzyme, 27
- Gilboa, Eli, 46
- GlaxoSmithKline, 66, 70, 72, 74–75
- gold particles, DNA protected by, 30
- Good Manufacturing Practice standards, 48, 54
- GP120 protein of HIV, 22–23
- Graham, Barney, 77, 78, 81
- Greenwood, Jim, 71
- growth factors, 60, 61, 62
- growth hormone, 30
- guanine (G), 36, 40, 51, 65
  - codon sequence, 6, 54, 80, 102
  - in DNA, 6, 101
  - and GC enrichment methods, 51, 54, 81
- H**
- Harvard University, 7, 13, 56–57, 58, 59
- heart disorders, 2, 62, 88, 99
- hemophilia, 22, 28
- hepatitis B, 72
- hepatitis C, 91
- Hepburn, Matt, 73
- Herceptin, 86
- Hilleman, Maurice, 24
- HIV and AIDS research, 11, 20, 22–23, 24, 29, 66
- self-amplifying RNA in, 91, 97

## 112 Index

H10N8 flu vaccine, 64–65  
H1N1 influenza virus, 70  
Hoerr, Ingmar, 45, 46, 47, 48–49, 53–54  
Hoge, Stephen, 62–63, 64  
Hopp, Dietmar, 3, 49  
Hungary, 36–37  
Hunter, Tony, 17  
Hutchinson, Geoff, 77

### I

immune response, x–xi, 3–4, 22, 31–32  
  acquired, 38, 40, 54, 64  
  antibodies in, 22, 86, 101 (*see also*  
  antibodies)  
  antigens in, 22, 29, 30, 80, 101  
  innate, xi, 36, 40, 41, 51, 54  
  to mRNA, 35, 40–41, 43, 47, 80, 84  
  parasitic, 35, 40, 41, 43, 58  
  to self-replicating RNA, 90  
  T cells in, 22, 40, 46, 102

*Immunity*, 35, 41, 57

immunoglobulins, 101. *See also*  
  antibodies

immunotherapy, 85–86, 87

Imperial College London, 89

In-Cell-Art, 52

Inex Pharmaceuticals, 93, 94, 95

influenza vaccines. *See* flu vaccines

Innovative Medicines Initiative, 28

Institut Cochin, 28, 29, 32, 48

Institut Mérieux, 30

Institut Pasteur, 45

insulin, 5, 11, 22, 27, 60

interfering RNA, 94–95, 98

  small interfering (siRNA), 42, 43, 60

interferons, 36, 37, 40

International AIDS Vaccine Initiative,  
  66, 72

### J

Jacob, François, 6, 13

Jansen, Kathrin, 82

Jenner, Edward, 4

Johns Hopkins University, 26

Johnson, Stephen, 29

Johnson & Johnson, 17, 52, 72, 73, 74, 75, 78

*Journal of Immunotherapy*, 49

### K

Kahn, Axel, 28

Karikó, Katalin, 35–44, 46, 56, 57, 60,  
  63, 80

Kastilan, Sonja, 84

Kerr, Ian, 36, 37

Khorana, Gobind, 6

Kourilsky, Philippe, 28

Krieg, Paul, 7, 13, 58

Krishnan, Shiv, 31

Kündig, Thomas M., 49–50

Kushner, Jared, 73

### L

Langer, David, 39

Langer, Robert, 56–57, 58, 96, 99

Lattès, Robert, 27

Lebleu, Bernard, 37

Lemmonier, François, 45

Lévy, Jean-Paul, 28–29

Lightspeed project of BioNTech, 81–82

Liljeström, Peter, 90–92, 97

Lion Biosciences, 49

lipids and liposomes, 25–26, 42–43,  
  92–97

  from Acuitas, 43, 52, 54, 73, 92–93, 95

  BioNTech using, 15, 52, 93, 94, 95, 96

  in cardiac fibrosis research, 99

  cationic, 10, 14–15, 16, 17, 18, 21, 90

  CureVac using, 52, 73, 93, 95

  immune response to, 31

  Karikó research on, 36–37

  Lipofectin, 15–17, 38, 42

  Malone and Felgner research on, 9, 10,  
  14–15, 18, 21, 31

  MC3 liposomes, 63

  Meulien research on, 28, 31

  in mice experiments, 21, 31

  Moderna using, 15, 52, 63

  Pardi research on, 44

  in respiratory virus membrane, 15

  stability of mRNA encapsulated

    with, xi

  supply problems, 43, 63

  Syntex research on, 15, 16, 18, 20, 93

Lipofectin, 15–17, 38, 42

Liu, Margaret, 24–26

- Lonza, 76  
 Loumaye, Ernest, 61  
 luciferase, 14, 21, 49
- M**
- MacLachlan, Ian, 43, 95  
 malaria, 98  
 Malone, Robert, 9–14, 16–18, 20–24, 25, 29, 31, 39  
 Manhattan Project 2.0 (Operation Warp Speed), 4, 66, 69–78  
 Marker, Russell, 15  
 market authorization, 10, 51  
 Martinon, Frédéric, 29–32, 40, 48  
 Massachusetts Institute of Technology, 6, 7, 56, 59, 92, 96  
 McLellan, Jason, 24, 77, 78, 81  
 MC3 liposomes, 63  
 measles virus, 72  
 melanoma, 47, 49  
 Mello, Craig, 94  
 Melton, Douglas, 7, 13, 58  
 Merck, 19, 20, 65, 70, 82, 91  
     flu vaccine research, 24–26, 30  
     in Operation Warp Speed, 72, 73, 74, 75  
 Mérieux, Alain, 30  
 Mérieux, Rodolphe, 26  
 messenger RNA. *See* mRNA  
 Meulien, Pierre, 28, 30–32, 40, 48  
 mice experiments, 21–22, 25, 29, 45–46, 47  
     on bird flu virus, 69  
     on flu vaccines, 64  
     liposome-coated mRNA in, 31–32  
 microRNA, 99  
 Middle East respiratory syndrome coronavirus, 78  
 Moderna, x, xi, 55–67, 70  
     cancer research, 64, 65, 84  
     and CureVac vaccine approach compared, 53, 66  
     cytomegalovirus research, 66–67, 72  
     delivery formula for vaccines, 81  
     dosage of COVID-19 vaccine, 52, 81, 91  
     efficacy of COVID-19 vaccine, 52  
     FDA approval of mRNA vaccine, 26  
     industrial RNA production, 97  
     lipids used by, 15, 52, 63  
     microRNA in heart therapy research, 99  
     Moore at, 64, 72, 99  
     Norwood facility of, 64–65, 76  
     in Operation Warp Speed, 72, 73, 74, 75, 76  
     principles behind COVID-19 vaccine of, 10, 35  
     pseudo-uridine used by, 80–81  
     spike protein shape in COVID-19 vaccine of, 78  
 monkey experiments, 61  
 monoclonal antibodies, xiii–xiv, 50, 84, 85–86, 98  
 Monod, Jacques, 6, 13  
 Montgomery, Donna, 25  
 Moore, Melissa, 64, 72, 99  
 Moussa, Pierre, 27  
 mRNA, x–xiii  
     in autoimmune diseases, xiii, 2, 88  
     Bancel on therapeutic uses of, 59, 64  
     BioNTech research on, 79 (*see also* BioNTech)  
     in cancer, 50, 64, 86–87, 88 (*see also* cancer)  
     in COVID-19 vaccines (*see* COVID-19 vaccines)  
     CureVac research, 50–53  
     in cystic fibrosis, xiii, 2, 39, 65, 96–97  
     definition of, 101  
     discovery of, 13  
     dosage of, 50, 52, 53, 60  
     end cap of, 36, 51  
     enzymes affecting, 3, 7  
     in flu vaccines, xii, 24–25, 44, 52, 64–65  
     French research on, 27–33  
     in GC enrichment method, 51  
     in heart disorders, 2, 62, 88, 99  
     immune response to, 31–32, 35, 40–41, 43, 47, 63, 80, 84  
     industrial production of, 48, 54, 61, 65, 76, 83  
     injection sites, 60  
     instability of, 7, 19–20, 54

114 *Index*

mRNA (*Continued*)

Karikó on potential therapies with, 38, 39, 40  
laboratory production of, 13–14, 25, 31  
lipid-coated, xi, 9, 10, 25 (*see also* lipids and liposomes)  
mail carrier metaphor on, 3–4, 7  
Moderna research on, 55 (*see also* Moderna)  
naked, 22, 25  
noninflammatory, 40  
patent applications on, 47 (*see also* patent applications)  
proof of existence, 5–6, 13  
pseudo-uridine as invisibility cloak for, 40–41, 60  
safety of, xi, 23–24, 47  
speed in vaccine development, x, xiii, 1, 69–78  
mRNA printers, 53  
multiple sclerosis, 2, 88  
muscle, protein production in, 21–22, 25, 29  
muscular dystrophy, xiii

**N**

naked DNA, 21–23, 25, 26  
naked RNA, 21–22, 25, 30, 46–47  
National Institute for Medical Research, 10, 14  
National Institute of Allergy and Infectious Diseases, 77  
National Institutes of Health, 23, 38, 77, 78  
*Nature*, 32, 56, 58  
neoantigens, 85, 86, 87  
*New England Journal of Medicine*, 80  
Nirenberg, Marshall, 6  
Nixon, Richard, 11  
noncoding RNA, xiv  
Norwood facility of Moderna, 64–65, 76  
Novartis, 11, 59, 65, 70, 83, 86  
bird flu virus vaccine, 69, 70, 98  
Novavax, 72, 73, 74, 75, 78

**O**

Obama, Barack, 57  
Ochoa, Severo, 6

Onpatro, 43, 95, 96  
Operation Warp Speed, 4, 66, 69–78  
Orphan Drug Act (1983), 62  
Ostro, Marc, 14  
Oswald, Andrin, 65  
Oxford University, 72, 74, 75

**P**

papillomavirus vaccine, 72, 82  
parasitic immune response, 35, 40, 41, 43, 58  
Pardi, Norbert, 43–44  
Parker, Suzanne, 24  
Pascolo, Steve, 45, 48–50, 51  
Pasteur-Mérieux, 30, 32  
patent applications, 16, 17, 18, 22  
of CureVac on GC rich method, 51  
in France, 32  
on protamine encapsulation, 48  
of University of Pennsylvania, 41–42, 63, 81  
of University of Tübingen, 47  
Perna, Gus, 73  
Pfizer, 70, 76, 82–84, 96  
Pfizer-BioNTech vaccines, 26, 44, 52, 70  
dosage of, 91  
lipid nanoparticles in, 15, 95, 96  
in Operation Warp Speed, 72, 74, 75, 76  
principles behind, 10, 35  
spike protein shape in, 78  
pH, and safety of lipids, 93–94  
plasmids, 13, 36–37, 61  
pneumococcal vaccine, 82  
polio, 12, 14  
Precision Nanosystems, 98  
Pprevnar 13 pneumococcal vaccine, 82  
primate experiments, 61–62  
*Proceedings of the National Academy of Sciences*, 10–11, 14–15  
proline, 81  
protamine, 48  
proteins, 3, 6, 21–22, 46, 77–78  
definition of, 101–102  
and DNA, 2, 6, 13, 21–22, 29–30, 59  
F protein of RSV, 77, 78  
interfering RNA blocking production of, 94

- recombinant, 27, 28, 72, 74, 84
- self-replicating RNA in production
  - of, 94
  - spike protein (*see* spike protein of coronavirus)
- Protiva, 42–43, 95
- pseudo-uridine, 40–41, 42, 58, 60, 73, 80–81
  
- R**
- rabies vaccine, 52, 53, 73
- Rammensee, Hans-Georg, 45–46, 47, 50
- Rappuoli, Rino, 69
- recombinant proteins, 27, 28, 72, 74, 84
- Redfield, Robert, 73
- replicase, 91
- Replicate Biosciences, 98
- respiratory syncytial virus, 77, 78
- retroviruses, 11, 12, 57
- reverse transcriptase, 12
- Rhodes, Gary, 24
- ribonucleases, xi, 3, 18
- ribosomes, 6, 13, 14, 18
  - capping of mRNA affecting recognition by, 36, 51
  - identification of RNA by, 81
- RNA
  - codon sequence in, 6
  - definition of, 102
  - discovery of, ix
  - immune surveillance for, xi
  - industrial production of, 97
  - injection sites, 50
  - instability of, 7, 19–20, 54
  - interfering (RNAi), 94–95, 98
  - messenger, 101 (*see also* mRNA)
  - microRNA, 99
  - naked, 21–22, 25, 30, 46–47
  - noncoding, xiv
  - SARS-CoV-2, x, xii
  - self-amplifying (saRNA), 89–92 (*see also* self-amplifying RNA)
  - small interfering (siRNA), 42, 43, 60
  - transfer, 5–6, 40
- RNA: Life's Indispensable Molecule* (Darnell), 5
- RNARx, 41–42, 43
  
- Roche, 11, 62, 86, 88
- Roman, Richard, 15, 16
- Rossi, Derrick, 56–58, 60
- Rutgers University, 6
  
- S**
- safety
  - of DNA vaccines, 26, 47, 74
  - of lipids, 93
  - of mRNA vaccines, xi, 23–24, 47
  - in Operation Warp Speed, 71–72, 75
- Şahin, Uğur, 44, 74, 79–87
- Salk, Jonas, 12
- Salk Institute, 9, 12–14, 17–18, 20
- Sanger, Fred, 5
- Sanofi, 70, 96
  - in Operation Warp Speed, 72, 73, 74–75
- Sanofi Pasteur, 52
- SARS-CoV-2 RNA, x, xii
- Schrum, Jason, 60
- Science*, 22, 29, 31, 32, 41
- Scripps Institute, 39
- Selecta Biosciences, 58
- self-amplifying RNA (saRNA), 89–92, 94
  - BioNTech testing of, 73, 81
  - in bird flu virus vaccine, 69, 98
  - microdoses with, 97
- Semliki virus, 89, 90
- Sharp, Phillip, 6, 7
- Shatkin, Aaron, 6, 36
- Shire, 96, 97
- Slaoui, Moncef, 4, 66, 70–77
- small interfering RNA, 42, 43, 60
- spike protein of coronavirus, x–xi, 7, 22
  - and antigens, 101
  - BioNTech research on, 80, 81, 83
  - mRNA coding for, xi, 72, 80
  - shape of, 23–24, 77–78
  - stabilization of, 78
- spinal muscular atrophy, xiii
- Springer, Tim, 57, 60
- stabilization technology, 78
- Stem Cell*, 58
- stem cells, 57, 58
- Stratagene, 31

116 *Index*

- Strüngmann, Andreas, 86  
Strüngmann, Thomas, 86  
swine influenza, 48  
Syntex Research Institute, 15, 16, 18,  
20, 93  
Szostak, Jack, 58
- T**
- T cells, 4, 22, 40, 102  
in cancer, 45, 46  
in cardiac fibrosis, 99  
in flu vaccine research, 24, 25, 26  
in HIV infection, 29  
Rammensee research on, 45–46, 47  
in response to mRNA, 31, 32, 47  
T4 cells, 29  
T8 cells, 29, 31  
Tekmira, 42–43, 63, 95  
Temple University, 37, 38  
Thermo Fisher, 18  
thymine (T) in DNA, 6, 101  
Tinguely, Jean, 2  
Toll-like receptors, 41  
Tomasz, Jenő, 36  
transcription, xi  
transfer RNA, 5–6, 40  
Transgène, 27–28, 30, 32  
TransIT, 58  
Translate Bio, 96, 97, 98  
Trilink, 51  
Trump, Donald, 4, 38, 53, 67, 71, 75, 82  
Türeci, Özlem, 79, 80, 84, 85, 88  
T7 virus, xi
- U**
- University of Bonn, 41  
University of British Columbia, 92  
University of California, Irvine, 15  
University of California, San Diego, 11,  
12, 17, 20, 22  
University of California, San  
Francisco, 13  
University of Colorado, 6, 7  
University of Illinois, 10, 14  
University of Pennsylvania, 33, 43–44  
BioNTech research program with, 88  
gene therapy research at, 94  
Karikó at, 35–36, 39, 41–42, 43  
patent of, 41–42, 63, 81  
Weissman at, 35–36, 41–42, 44, 99  
University of Pittsburgh, 6  
University of Texas, 29  
University of Tübingen, 33, 45, 47, 48  
University of Wisconsin, 21, 46  
uridine (U), 65  
codon sequence of, 6, 54, 80–81, 102  
innate immune response to, 40, 51  
Karikó and Weissman research on, 36,  
40–42, 47, 80–81  
and pseudo-uridine, 40–41, 42, 80–81  
urokinase, 39
- V**
- Vaccine Research Center at NIH, 77, 78  
vaccines, x–xiii  
AIDS, 22–23, 24, 29, 66  
bird flu virus, 69, 70  
cancer, 46, 50, 51, 53, 64  
COVID-19 (*see* COVID-19 vaccines)  
cytomegalovirus, 66–67, 72  
DNA (*see* DNA vaccines)  
flu (*see* flu vaccines)  
polio, 12  
rabies, 52, 53  
recombinant protein, 72, 74  
self-amplifying RNA, 89–91  
traditional, x, 71–72  
Zika virus, 66  
Vaccines Day of Moderna (2021), 63, 64  
Valcárcel Juárez, Juan, 7  
Valerio, Dinko, 17  
Verma, Inder, 9, 10, 12, 14–15, 20  
Vertex, 65  
vesiculovirus, 72  
Viagene Biotech, 20  
Vical, 20, 21, 22, 23–24, 30, 91  
von Behring, Emil, 83  
von Bohlen und Halbach, Friedrich, 49  
von der Mülbe, Florian, 48
- W**
- Wall Street Journal*, 82, 83  
Warren, Luigi, 57–58  
Watson, James, 5



- Wattendorf, Dan, 66  
Weide, Benjamin, 49  
Weissman, Drew, 35–36, 38, 40–44, 46  
  cardiac fibrosis research, 99  
  modified RNA nucleic base of, 40–42,  
    56, 57, 60, 63, 80  
  on supply problems for lipid nano-  
    particles, 43, 63  
Weissmann, Charles, 27  
West Nile virus, 26  
Whitehead Institute, 59  
Wolff, Jon, 21–22, 25, 29, 39  
  
World Health Organization, 24, 69,  
  79–80  
Wyeth, 82  
  
**Y**  
Yale University, 41, 98  
Yamanaka, Shinya, 57  
  
**Z**  
Zika virus, 66, 70  
Zinknagel, Rolf, 44, 85  
Ziwawo, Cynthia, 77