# Subject Index

## A

Absorption-airways gas transport, 115-117, 121 Absorption efficiency, 119, 210(fig), 121(table)Acid aerosols and asthma, 207-213 sensitivity, 49 Adaptive immune system, 33, 34 Adolescent subjects, 207 Adverse health effects of ambient air pollutants, 6-8 Aerosol bolus technique, 97, 127-138 Aerosol boluses diagnostic use, 137 dispersion in exhaled air, 130–131(figs) dispersion in patients with asthma or emphysema, 132(fig) inhalation apparatus for lung studies, 128(fig) technique, 127 Aerosols airway hyperresponsiveness, 50 and asthma-adolescent subjects after exercise-induced bronchospasm, 208 forced expiratory volume (FEV), 210(fig) methods of study, 208-209 physical characteristics of subjects, 209(table)pulmonary function values, 210(table) results, 209 Age factors relationships between human and animal ages, 151 sensitivity to hyperoxia in animals, 24 susceptibility to inhaled pollutants, 148 Aged populations affected of increases in pollutant levels, 149 Air pollution acute respiratory responses, 75 adverse health effects, 7-20 asthma, 68

chronic respiratory illness, 174 epidemiologic studies, 7-20, 184 health effects, 8-9, 49, 57 individual response—variability, 76 inhaled chemicals, 100-110 oxidants and bacterial infections, 184 standards development, 6-20 study group responses, 55, 57 susceptible populations, 3-4, 6-20, 141 Air pollution episodes, 3-5Air pollution exposure, asthmatic subjects-selection for study, 61(table) Air quality guidelines World Health Organization, 110 Airborne gaseous contaminants—upper respiratory tract airflow through different airways, 102-103 chemical and physical properties, 100 effects of ventilation parameters, 101(fig)scrubbing, 105 Airflow patterns through the human head, 101(fig) Airway anatomy, 113 Airway charting tracheobronchial tract, 132 Airway gas transport, 115, 116(fig), 117(table)Airway hyperreactivity/reactivity allergens, 39 asthma, 49 inhaled chemicals, 39 nitrogen dioxide and asthma, 218-223 ozone exposure, 188 respiratory tract infections, 39 Airway hyperresponsiveness, 49–52 Airway inflammation, 52 Airway resistance, 103(fig), 130(table), 195 Airway responsiveness—asthma See also Airway hyperresponsiveness epidemiological studies, 68-74 Airway scrubbing, 100-110

Airway smooth muscle mechanisms for minimizing contraction, 50(fig), 51(tables) Airway transport model, 124 Allergy, 141, 144 Alveolar macrophage (AM) cells in lavage fluids, 36 function in animals, 187 principal phagocytic cell in airways, 35 Alveolar ventilation, diffusion and perfusion, 118(fig), 120 Ambient air pollutants physiological response, 76-77 susceptible populations, 6–19 Ambient air standards, 6-19 Agina pectoris adverse effects ambient air pollutants, 9-11 of carbon monoxide exposure, 10 Animal studies—literature review, 149, 150(table)Antimicrobial defense of lower respiratory tract, 187 Asbestos fibers tissue injury in animals caused by inhalation of particulates, 28(fig), 30 Asthma acid aerosols, 207–213 aerosol boluses, 132 air pollution exposure, 61(table), 68 airways responsiveness, 4, 49-55, 58 and wheeze, 143 clinical and epidemiological studies, 57-67 environmental pollution conditions, 219 - 220epidemiology, 57-67, 219 identification of susceptible populations, 56, 57 in children, 143, 144 mechanisms of susceptibility, 40-41 nitrogen dioxide exposure, 60(table), 218–220, 221(table) nonuniformity of ventilation distribution, 55 occupational, 38-39, 40(table) ozone effects, 56 ozone or oxidant exposure, 60(table) population surveys, 62(table) role of immune cells and mediators in pathogenesis, 39 sensitivity, 49 sulfur dioxide-induced bronchocon-

striction, 195

susceptibility, 58 sulfur dioxide exposure, 59(table) Asthmatics air pollution exposure, 55-56, 61(table), 57-67 airway responsiveness inhaled antigen, 216 nitrogen dioxide, 218 ozone, 215 sulfur dioxide exposure, 59(table) sulfur dioxide inhalation in exercise and resting, 196, 198 exercise, 198 forced expiratory volume, 62(table) health effects of sulfuric acid inhalation. 207 sulfur-dioxide exposure, 59(table)

#### B

Bacterial infections-oxidants, 184 BAL. See Bronchoalveolar lavage. BALF. See Bronchoalveolar lavage fluid. Biological markers. See Immunological markers Blood flow patterns during exercise, 113(table), 115 Bohr model—gas transport, 117 Breathing pattern variations climatological factors, 102-103 exercise, 104 oronasal breathing, 102-104 Bronchial circulation, 115 Bronchial hyperreactivity general population, 144 Bronchial responsiveness of asthmatic subjects epidemiological studies, 68-69 Bronchiolitis, 55 Bronchitis early childhood, 143 Bronchoalveolar lavage (BAL), 35, 188 fluid (BALF) Bronchoconstriction in asthmatics sulfur dioxide exposure, 195-199 Bronchoconstrictor effects of air pollutants, 52 Bronchoconstrictor stimuli, 50 Bronchospasm, exercise induced, 208

## С

Carbon monoxide exposure Criteria Documents for CO exposure EPA-600/8-79-011, 9 EPA-600/8-83-033F, 10

EPA-450/5-84-004 45FR 55066 (Federal Register, August 1980), 10 health effects, 6-19 susceptible populations, 4, 6 Carboxyhemoglobin biological dose indicator for carbon monoxide, 100 carbon monoxide reaction with hemoglobin, 8 Cardiovascular patients adverse effects of ambient air pollutants, 9-11 of carbon monoxide exposure, 10 CASAC. See Clean Air Scientific Advisory Committee Cell injuries in animal lungs from breathing oxidant gases or inhaling particulates, 27(fig) Charting human airways, 127 Chemiluminescent detector determinations of nitrogen dioxide concentrations, 105 Chemotaxis, 34 Childhood, early lower respiratory illness, 142 Children susceptibility to chemicals, 3 Chronic obstructive airways diseases, 141 - 147Chronic obstructive pulmonary disease (COPD), air quality criteria document, 175 risk factors, 175(table) Chronic respiratory disease pathogenesis, 227, 228(fig) Circulation-blood flow, 115 Clean Air Act (CAA) of 1970. See Standards Clean Air Scientific Advisory Committee (CASAC), 6-19 Clearance, 127 Climatological factors in breathing patterns, 103 Clinical and epidemiological studies subject selection, 64-65 COPD. See Chronic obstructive pulmonary disease Criteria pollutants, 6–7 Cystic fibrosis, 55

#### D

Defense mechanisms animal response to oxidant exposures, 30(fig) Deficiencies of nutritional components affect lung size, structure and function, 170 Deposition of insoluble particles in human subjects, 92 Dermatophagoides pteronyssinus (house dust mite), 39 Diagnostic methods for study of human lungs, 127 Diffusion, alveolar, 118(fig) Diffusion limited behavior absorption efficiency, 119, 120(fig) Diffusion, pulmonary, 111, 116, 117(fig) Diffusion resistance, 116, 117(table) Disease individual predisposition, 3 mechanisms of inhaled pollutants, 224 Dispersion—aerosol bolus, 127–131(figs) Dose-response inhaled pollutants, 224 Dosimetry biological indicators of dose carboxyhemoglobin in blood as measure of carbon monoxide exposure, 100 exercise factors, 91-99, 111-126 lungs, 100–110 respiratory tract susceptibility to inhaled gases and particles, 91-99 mathematical models, 97

## Е

Elastin metabolism (lung elastin) animal studies, 166-167 Emission standards for hazardous pollutants, 7 Emissions respiratory effects of indoor air pollutants, 40 Emphysema aerosol boluses, 132 variations in gas distribution, 55-56 Emphysema-like lesions nitrogen dioxide exposure, 12 Environmental exposure to inhaled pollutants, 230 Environmental exposure chambers, 76 Environmental pollutants effects of inhalation into tracheobronchial tree, 113 immunological markers of susceptibility, 33 safety standards for exposure, 23 tobacco smoke-passive exposure in childhood, 146

Environmental Protection Agency (EPA) See also Standards Clean Air Act, 6-19 Epidemiologic studies air pollution, 8-14, 184airways responsiveness, 68-72 animal infective models, 185 asthmatics, 57-67 methodology, 57-67, 72 Epithelium possible barrier to bronchoconstrictors, 50 Exercise airflow patterns in upper respiratory tract, 101(fig) airway concentrations-response, 124-125 asthmatics, 190 effect on distribution of ozone dose, 123(fig) effect of turbulance in airways, 114(fig) experimental regimen for gases and particles, 91 influence on regional respiratory tract dosimetry, 92-93 regional dosimetry, 96, 97(fig), 110, 111 - 126upper airway scrubbing, 100 Exercise-induced bronchospasm, 208 Experatory volume, forced. See Forced expiratory volume (FEV) Experimental design for clinical and epidemiological studies of asthma, 57 Expired aerosol boluses-dispersion, 129 Exposure-dose response relationships inhaled pollutants, 4-5, 229, 230(fig) Exposure duration asthmatics exposed to sulfur dioxide, 199 - 200Exposure temperature/humidity bronchoconstriction in asthmatics exposed to sulfur dioxide, 200-202F Feedback mechanisms in immune system, 34 Fetus, 3-4 Fiberoptic bronchoscopy in diagnosis of lung disease, 35, 188

Forced expiratory volume (FEV) asthmatics, 62–64(figs), 69(fig), 210(fig)

## G

Gas stoves source of nitrogen dioxide, 219 Gas transport in airways exercise and regional dosimetry, 111– 126 Gas uptake from respiratory zone, 118(fig) Gaseous contaminants—airborne, 100

## H

Hazardous air pollutants adverse health effects, 7 Clean Air Act of 1970 Section 109(b) (1), 7 Section 112, 8 national emission standards, 7 Health effects of air pollution, 6-19, 49, 57-58 Host factors asthma studies, 57 House dust mite may induce airway hyperreactivity, 39 Human alveolar macrophage, 188 Human exposure research, 13–14, 91 Human exposure to oxidants, 188 Human immunodeficiency virus, 187 Human respiratory infection ozone may increase susceptibility to experimental bacterial infection, 185 Human respiratory tract aerosol boluses for diagnostic purposes, 137 ozone irritation, 174 Hygroscopic particles respiratory tract deposition, 91, 94, 95(table) Hyperoxia acute lung injury, 23 animal studies, 23-31 age sensitivity, 24 effects of lethal and sublethal levels in animals, 24, 25(figs) enhanced oxygen tolerance in younger animals, 163 Hyperreactivity in the lung, 41, 43 Hyperresponsive airways, 207 Hyperresponsiveness, 42, 51(tables) Hypersensitivity pneumonitis, 38, 39(tables), 40(table)

#### I

Immune response reaction to infectious agents, 33 Immune system control mechanisms, 33–34, 42 Immunologic lung disease. See Lung disease Immunological markers of susceptibility chemicals associated with work environment, 38, 39(tables) hypersensitivity pneumonitis, 38, 39(table) modulation and detection, 35-37of sarcoid in BAL, 37(table) prediction of susceptibility to inhaled pollutants, 32–46 questions, 34-35 respiratory tract dosimetry, 91-99 response of laboratory animals, 149 response to environmental stimuli, 34 susceptibility—age and aging in animals, 157-159 susceptibility of immature animals, 153 - 157susceptibility of maturing animals, 158– 159 susceptible individuals, 224–231 Inflammation airway responsiveness, 49-54 markers, 34, 41 reaction to injury, 33 Inflammatory lung disease. See Lung disease. Inhalation technique for study of human lung characteristics, 127 radioactively labelled particles for smokers and nonsmokers clearance curve, 135 Inhalation toxicology airway branching patterns, 30 animal studies, 23, 29, 30 asthma and nitrogen dioxide, 218-222 tissue injury, 30 Inhaled pollutants and toxicants age factors, 148 chemicals, 100-110clinical and epidemiological studies of asthma, 63(figs) deposition in larynx, 98 deposition in lung, 106-107 dose-response, 224 gas pollutants and genetic control, 41 immunological markers, 32–46

particles, 91-99 present standards reflect young-to-midaged adult population, 148 respiratory tract dosimetry, 91-99 response of laboratory animals, 149 susceptibility of aged animals, 159 susceptibility of aging animals to nitrogen dioxide, 157-158 to synthetic smog, 158 susceptibility of immature animals cigarette smoke, 157 diesel exhaust, 156-157 nitrogen dioxide, 153-154 oxygen, 156 ozone, 154-156 sulfur dioxide, 156 susceptibility of maturing animals, 158-159 susceptible individuals, 32, 37 Innate immune system, 33 Insoluble particles respiratory tract deposition in humans, 91–99 Interstitual lung disease. See also Lung disease. inherited familial idiopathic pulmonary fibrosis, 42 pulmonary sarcoidosis, 42 role of genetic factors, 42 Isocyanate immunologic testing of exposed workers, 42

## L

Lead See also Standards susceptible populations, 4, 7, 10-11 Lower airways, 111 Lower respiratory illness in early childhood, 142 respiratory syncytial virus, 142 Lung antioxidant defenses, 162 Lung disease, obstructive, inflammatory and interstitial bronchiolitis, 55 fiberoptic bronchoscopy, 36 immunopathogenesis, 36 individual variability-response to ozone exposure, 86 susceptible populations identification, 55 ventilation distribution, 55 Lung disorders, 32

Lung dosimetry lower airways gas transport, 111-126 upper airway scrubbing, 100-110 Lung elastin-metabolism animal studies, 166-167 Lung function affected by severe nutritional deficiencies, 170 age factors; 148 design of clinical laboratory studies, 180in children, 142-145 inhalation exposures to pollutants affected by age, 149 Lung function studies, 16, 41 Lung injury animal studies of sensitivity to pollutants, 23-31 caused by oxidant gases, 26, 27(figs), 29(figs) chronic damage from inhaled chemicals, 100 morphologic changes during exposure to hyperoxia, 25-26(figs) nonuniformity of ventilation distribution in asthmatics, 55 response to exercise, 111 Lung mass transfer coefficients, 111-126 Lung studies–aerosol boluses, 127–138 Lung tissue damage nitrogen dioxide exposure, 12 Lungs, human aging during adulthood, 152 antioxidant defense mechanisms, 162 growth from birth to adulthood compared to laboratory animals, 151 study of characteristics, 127 susceptibility to inhaled pollutants, 151 - 152

#### Μ

Mass transfer coefficients, lung, 111, 116(fig) Mathematical modeling airway transport model, 124(fig) Bohr model, 117, 122, 123(fig) exercise and dosimetry, 122–123 transport of insoluble gases, 123 Mechanisms of predisposition to disease inhaled pollutants, 3 metabolism, 3 vulnerability, 3 Metabolism mechanisms for predisposition to disease, 3 Modelling response

to identify responsive individuals, 79 Mucociliary transport

adversely affected by exposure to oxidants, 186

#### N

- NAAQS. See National Ambient Air Quality Standards
- Nasal airway resistance and airflow, 103(fig)
- Nasal breathing, 102
- National Ambient Air Quality Standards (NAAQS), 6, 227

See also Standards

National Emission Standards for Hazardous Air Pollutants (NES-HAP), 7

See also Standards

NESHAP. See National Emission Standards for Hazardous Air Pollutants

Nitrogen dioxide *See also* Standards air quality standards, 12–13 altered lung function, 12

- asthmatic subjects-selection for clinical studies, 60(table)
- effect on airway responsiveness in asthmatics, 52, 68
- emphysema-like lesions, 12
- epidemiology and asthma, 219-220, 221(table), 222
- exercise and dosimetry, 91
- exercise-related ventilatory changes, 108, 109(table)
- experimental measurement of upper respiratory tract scrubbing in test animals, 105, 106(fig)
- exposure, 13, 37-38
- lower respiratory tract (lung), 107
- pulmonary effects in asthmatics, 221(table)
- resistance, 38
- susceptible populations, 7, 10-11
- treatment with vitamin C, 222
- uptake in head and lungs of dogs, 108(fig), 109(table)

Nonspecific immune system, 33

- Nutrition
  - amino acid deficiencies, 162
  - antioxidant defense mechanisms copper, 162 selenium, 162 vitamin C, 163

vitamin E, 162 zinc, 162

#### 0

Obstructive lung disease. See Lung disease. Occupational asthma, 39, 40(table) Occupational exposures inhaled pollutants, 32–46 Oral breathing, 102 Oronasal breathing, 100 Oxidant effects on macrophage-virus interaction, 187 Oxidant exposure See also Ozone linked to susceptibility to infection, 189 relationship to chronic obstructive pulmonary disease, 174–175 relationship to respiratory infection, 182 Oxidant gas exercise and dosimetry, 96, 97(fig) lung injury, 26-27 See also Ozone Oxidant injury lower respiratory tract, 23-26 Oxidant pollutants modulation of immunological markers, 37 Oxidants bacterial infections, 184 exercise and regional dosimetry, 91-99 potential cocarcinogens or promoters, 169-170 viral infections-animal infectivity models, 185 Oxygen animal studies effects of low protein diet, 164 sensitivity to lung injury, 23-31 mortality of exposure, 25(fig) toxicity-animal studies, 163 Ozone or oxidant exposure See also Oxidant exposure, Standards air quality standards, 6-20animal studies on sensitivity, 27-28(figs)exercise and dosimetry, 91 airway responsiveness, 49-54 asthmatic subjects-selection for clinical studies, 60(table) epidemiologic studies, 214 experimental design for studies, 179 human exposure health effects, 14

human health consequences, 174 human lung uptake, 96, 97(fig) in asthmatics, 214-215 individual respiratory responses, 75, 82 - 84individual variability, 84-85 injury from inhaled oxidants, 183 lung function responses, 178–179(figs) population studies, 183 reactivity laboratory study-design, 177 respiratory effects, 85 risk assessment studies-design, 180(tables) susceptibility to inhaled pollutants, 224 susceptible populations, 6, 13–14, 23

#### P

Particle concentration monitoring aerosol bolus, 128(fig), 129(fig) Particle recovery from respiratory tract 133(fig) Particulate matter criteria documents, 6 deposition data, 93 exposures, 16-18 thoracic deposition, 93 tracheobronchial deposition, 93(fig) Passive tobacco smoke relationship to lung function in childhood, 144 Perfusion absorption efficiency, 120(fig), 121(table)Perfusion, alveolar, 118, 120 Perfusion-limited behavior absorption efficiency, 119, 120(fig) Perfusion, pulmonary, 111–126 Permeability, markers, 34 Phagocytosis defense mechanism of lung against infection, 35 measurement, 43 respiratory infection and oxidants, 187 Photochemical oxidants. See Ozone Pneumonitis, hypersensitivity work environment organic dusts, 38, 39(table) Pollutant gas dosimetry, 124-125 **Pollutants** ambient air, 6 environmental immunological markers of susceptibility, 33 safety standards, 22

Pollutants (cont.) exposure, 111-126 inhalation-individual responsiveness, 203 oxides of nitrogen, 3 ozone, 3 Polymorphonuclear neutrophils (PMN), 33, 36 Predisposition to disease, 3 Protein-calorie deficiencies animal studies, 165–166 Pulmonary circulation, 115, 118 Pulmonary condition defects, 55 Pulmonary diffusion, 111–126 Pulmonary effects of nitrogen dioxide in asthmatics, 221(table) Pulmonary fibrosis, 42 Pulmonary function changes in asthmatic adolescents after inhaling sulfuric acid, 207, 210-212 ozone exposure, 75–88 Pulmonary immune system, 36 Pulmonary perfusion, 111–126 Pulmonary responses of asthmatics sulfur dioxide-induced bronchoconstriction, 196-197 Pulmonary sarcoidosis, 42 Pulmonary uptake during exercise, 119 Pulmonary ventilation perfusion ratio, 111-126

#### R

Radioisotope measurements, 120 Reactivity to ozone-laboratory study, 177 Reproducibility of individual responses, 81 of oronasal switching point Respiration during exericse, 112–115 Respiratory health childhood factors related to adulthood, 141-147 Respiratory infections and oxidants, 182 in children, 141-147 relationship to chronic obstructive pulmonary disease, 174 susceptible population models, 141-147 Respiratory response-individual to ozone exposure, 75-76, 85 Respiratory symptoms, 195

Respiratory syncytial virus in early childhood, 142 Respiratory system inhaled pollutants, 148 Respiratory tract deposition of insoluble particles, 92 dosimetry of inhaled particles, 91–99 exercise and dosimetry, 91-99 infection may induce airway hyperreactivity, 39 particle dose, 95 susceptible individuals, 3 tracheobronchial and thoracic deposition curves, 93-94(figs), 95(table) Respiratory virus challenge defense mechanisms, 185-186 lung function review, 141-147 specific effects of oxidants, 186 Review—lung function, 141-147 Risk assessment, 43 Risk factor relationships-chronic respiratory illness design of studies, 176(table)

## S

Safety margin for air pollution, 7–20 Sarcoidosis immunological control mechanisms impaired, 36, 37(table) pulmonary-inherited, 42 Selenium deficiency enhanced toxicity of ozone, 163 rats more susceptible to hyperoxia, 163 Sensitivity to acid aerosols, 49 Sick building syndrome, 40 Smokers and nonsmokers aerosol bolus inhalation-lung studies, 135, 136(fig, table) Smokers' lungs, 33, 35-37 Smokers' response to ozone exposure, 85 Smoking relation to chronic obstructive pulmonary disease, 174 Smoking by children relationship to rate of growth, 144-145 SOD. See Superoxide dismutase Species sensitivity to lung injury, 23-31 to oxidant gases, 27 Specific immune system, 33, 34

Spirometry, 180 Standards air quality guidelines, World Health Organization, 9 ambient air pollutants, 6-20 EPA Clear Air Act of 1970 Co Criteria document EPA-600/8-79-011, 9 EPA-600/8-83-033F, 10 EPA-450/5-84-004, 10 Federal Register: 44 FR 8207, (Oct. 1979), 9 45 FR 55066, (Aug. 18, 1980), 10 Lead Criteria documents Federal Register: 43 FR 46246, (Oct. 5, 1978), 10Ozone Criteria documents EPA-600/8-84-020 (Aug. 1986), 14 36 FR 8186 (Apr. 30, 1971), 13 44 FR 8202 (Feb. 1979), 13 Particulate matter, Criteria Documents, NAAQS: 36 FR 8186 (Apr. 30, 1971), 15 49 FR 10408 (Mar. 20, 1984), 15 EPA-600/8-82-029 (1982), 15 EPA-450/5-82-007 (1982), 15 EPA-CASAC-87-101 (1986 addendum), 16 London mortality studies, 16 particle size indicators (Jan. 29, 1982 reaffirmed), 16 Standards development, 6-20 Statistical methods individual variability, 78–79 Sulfur dioxide See also Standards exposure asthmatic subjects-selection for clinical studies, 59(table), 68 bronchoconstriction in asthmatics, 195, 197, 204 exercise and dosimetry, 91 responsiveness variability in asthmatic population, 202-203, 207 Sulfuric acid effects asthma, 68 exercise and dosimetry, 91 health effects in asthmatics, 207 Superoxide dismutase (SOD) pulmonary activity in different species, 24(table)

Susceptibility immunological markers, 32-46 overview, 3-6 Susceptible populations to air pollution age factors, 148-161 air pollution, 3-4, 6-20, 141 animals, 23-31asthma, 55, 227 bronchoconstrictor effects, 52 children, 3 effects of indoor air pollutants, 40 effects of inhaled pollutants, 148, 225, 226(fig) identification, 6, 56 immunological markers, 32-46 inhaled pollutants, 43 mechanisms, 41 responses, 6-19 standards, 6–19

## Т

Tachykinins effect on airway smooth muscle, 50 Thoracic deposition of insoluble particles, 92-93, 94(fig) Tissue injury in animals caused by inhalation of particulates, 30 Tobacco smoke exposure in childhood, 146 Toxicology, susceptibility to inhaled pollutants, 148 Tracheobronchial tract aerosol boluses-technique for diagnostic studies, 137 charting, 137 deposition of particles, 93–94(figs), 95(table) particle charting of airways, 134

## U

Upper respiratory tract efficiency of particle removal during rest and exercise, 98 upper airway scrubbing, 101, 105 Uptake, *See* Absorption.

## v

Variability acute physiological response among individuals exposed to comparable inhaled doses of ozone, 76-83 Variability (cont.) in individual response and susceptibility, 3-4, 76 methods for measurement of individual response, 77-78 ozone responsiveness, 82-86 Ventilation, alveolar, 118 Ventilation and blood flow, during exercise 113(table), 120 Ventilation distribution, nonuniformity, in asthmatics, 55 Ventilation factors bolus technique, 137 exercise related, 106-108, 109(table) exposure duration, 199 gas transport, 118, 124-125 patterns during exercise, 113(table) Ventilation-perfusion ratio, absorption efficiency, 119, 120(fig) Ventilation, pulmonary, 111-126 Viral respiratory infections in lower levels of small airway function, 145

animal studies, 166 Vitamin C in synthesis of collagen and elastin, 167 inhibits airway reactivity following exposure to nitrogen dioxide, 222 Vitamin E deficiency enhanced toxicity of ozone, 163 ratio of polyunsaturated fatty acids, 169 Vulnerability mechanism for predisposition to disease, 3

Vitamin B-6 deficiency

## W

Wheezing. See Asthma, Bronchitis World Health Organization—European Region air quality guidelines, 9