Index

abdominal ionizing radiation, see radiotherapy abnormalities, children's health outcomes, see congenital abnormalities acetamide, 26-27, 18, 19-20 acquired immunodeficiency syndrome (AIDS), 46 activin A, 205, 208 addonitol, 27-28 adolescents with cancer, 63-69, 195-196 AID (artificial insemination by donor), 46,48 alcohols, 27 alkylating agents, 57-58, 189 amide cryoprotectants, see acetamide; formamide; methanamide anejaculation, 48-49 angiogenesis, transplantation and, 191, 225 angiogenic granulation tissue, 221 animal breeding electroejaculation use, 48 sperm cryopreservation, 39-40, 41 animal studies follicle culture, 200, 204 McGill Cryoleaf efficacy, 148 ovarian grafts, 219 ovarian tissue grafts, 218 whole ovary cryopreservation, 233-234, 242, 245-248 anonymity, sperm donors, 46-47 anti-Müllerian hormone folliculogenesis, 200-201, 205, 207 ovarian tissue transplantation, 224, 226 antioxidant treatment, 220 antral follicles in vitro development, 208 puncture, 213, 214 apoptosis, culture conditions, 206-207 aquaporins, 17 aquaporin 3, 18 early embryos (mouse), 20 morulae (mouse), 19, 20

oocytes (mouse), 17-18 aqueous solutions, 3 arabinose, non-penetrating CPAs, 29 Arrhenius activation energy, 17 ART (assisted reproductive technology) CPA use, 25, 33 embryo cryopreservation, 67 ice crystal prevention, 12 outcomes, 178-182, 179 adverse effects, 182 after oocyte cryopreservation, 178 babies' neonatal development, 182 multiple pregnancy, 67-68 sperm cryopreservation, 40 vitrification roles, 131 artificial insemination by donor (AID), 46,48 artificial shrinkage, blastocele, 99-100, 101 aseptic vitrification, 158-159, 165 blastocysts, 106-107, 109-112, 163-164 applications, 108-109 outcomes, 110 protocols, 109 cooling speed, 106-107 embryo carrier devices, 107 hermetically sealed, 106-107 illustrated, 158, 159 GV oocytes, see germinal vesicle oocytes outcomes, 109 protocols, 108, 159 solutions, 108 vs. non-aseptic vitrification, 108-109 assisted reproductive technology, see ART asthenozoospermia, 48 autoimmune diseases, 40, 151-152, 190 autotransplantation, see transplantation azoospermia, 57-58 sperm retrieval, 51, 52-53

bacterial agents, risk, 139 basal culture conditions, 204 basic fibroblast growth factor, 205 biochemical pregnancies, 178 biological carriers, sperm cryopreservation, 53-54 biomaterials, ownership and disposition, 253-254 biopsy blastocysts, 102 embryos, 70, 81, 90 biospectroscopy, 123 Biot-Fourier equation, 159 blastoceles, 95-96 shrinkage, 99-100, 101, 111 blastocyst aseptic vitrification, 106-107, 109-112, 163-164 applications for, 108-109 in vitro development for, 109-110 outcomes, 110 protocols, 108, 109 blastocyst cryopreservation, 95 methods, 97-99 optimal stage for, 82, 96 pregnancy outcomes, 95 selection, 72 slow freezing, 99 water/CPA movement, 21 blastocyst vitrification, 99 carrier devices, 107 Cryoloop, 98 Cryotop, 98, 100, 102 electron microscopy grid, 97 culture methods, 96-97 in vitro development, 108-109, 162 optimal stage for, 100-101, 102, 164 pregnancy rates, 160 protocol, 69 rapid freezing, 157-158 selection for, 70, 77, 111 structural features, 95-96 two-step treatment, 21 blastocysts after thawing, 101 bovine, 31 cooling rate and outcomes, 89 cryodamage, 71 for transfer, 100-101

advantages, 97, 157

Index

disadvantages, 96, 97 murine, 17, 18 blastomeres, 95 cryodamage to, 71 in embryo selection, 91, 93 in oocyte quality, 123 bone morphogenetic proteins, 200-201,205 boys cancer, 58 prepubertal, 59-61 BRC-ABL detection, 229 breast cancer, 151, 190 1,3 butanediol (butylene glycol), 27 butylene glycol (1,3 butanediol), 27 cancer patients, xi adolescents, 63-69, 195-196 ART outcome, 184 embryo cryobanking, 68, 251 evaluation for fertility preservation, 223 fertility preservation, 190-191 female, 68 fertility preservation options, 62-63, 190-191 gonadotoxic therapies, 189-190 oocyte cryopreservation, 150-153, 251 ovarian stimulation, 144-145 ovarian tissue cryobanking, 189, 190, 213, 218, 221 evaluation for transplantation, 228 histological analysis, 215-216 indications for, 190 safety of, 226-229 storage protocol, 221-222 pregnancy complications after treatment, 251 pre-transplantation evaluation, 222 primordial follicle cryopreservation, 200 recurrence risk ovarian tissue autotransplantation, 252 SSC contamination, 62 whole ovary transplantation, 195 sperm cryobanking, 40, 46, 51 SSC transplantation, 59-61 treatment delay, 251 treatment planning, 58-59 young patients, 59, 63-68, 248, 252-253 cancer susceptability genes, 253 carrier devices, 133, 146

oocyte vitrification, 132-135, 133 effectiveness, 134-135 safety, 138-139 sperm cryopreservation, 53-54 see also embryo carrier devices; McGill Cryoleaf cell membrane permeability, 4, 10-11, 16 cryobiological property, 16 cryoinjury and, 10-11 developmental changes, 21 measurement, 16-17 penetrating CPAs, 25 transport channels, 4, 10-11, 17 cell membranes, integrity, 161 cells cryoinjury, 1-2, 4 permeability, 4 proliferation in vitro, 207 channel diffusion, 16, 17 early embryos, 20 morulae, 16-22, 19, 20 oocytes and morulae, 17 chemotherapy, see gonadotoxic chemotherapy childhood cancer, 57, 63-68, 248 ovarian tissue cryopreservation, 189, 252-253 sperm cryopreservation, 58-59 testicular tissue cryopreservation, 59 children, from oocyte cryopreservation, 127-128, 132 chilling, cryobiological property, 16 China, donor sperm cryopreservation, 46-48 choline-based freezing media MII spindle maintenance, 124-125 oocyte cryopreservation, 116, 122-123 chromatin abnormalities, 163 chromosomal abnormalities, 180-181 classic technique slow-freezing oocytes, 115, 116 sperm cryopreservation, 41 cleavage stage embryo cryopreservation, 68-69, 70 comparative studies, 81-82, 96 vs. blastocyst, 102 vs. pronuclear, 82 cryodamage, 71 day 2, 81-82, 89, 90 day 3, 89, 90 selection for, 71-72, 77 clinical assisted reproduction, see ART (assisted reproductive technology) co-culture, blastocyst cryopreservation, 95

colligative properties, 4 concentration, in CPA toxicity, 31-32 congenital abnormalities ART and, 179-181, 180 oocyte cryopreservation and, 127-128, 183-184 consent, see informed consent contamination risk, in vitrification, 84, 98-99, 158 cooling rate and ice formation, 11 aseptic vitrification, 106-107, 160 carrier devices and, 135-137 danger zones, 13 developmental stage and outcomes, 89 donor egg bank protocol, 172-173 minimum volume cooling protocol, 172-173 phase diagram for CPAs, 12-14 slow-cooling cryopreservation, 77, 121 vitrification, 14, 92, 134, 137-138 whole ovary cryopreservation, 243 cortical tissue, see ovarian cortical tissue CPAs (cryoprotectants), 24, 25, 33 animal model studies, 148 aseptic vitrification, 106-107, 110-112, 158 blastocyst cryopreservation, 99 aseptic vitrification, 110-111 slow-freezing, 99 vitrification, 99 cell permeability to, 12 combination, 13-14 concentrations of, 14, 137 172 cryodamage reduction, 31 embryo cryopreservation, 68-69, 76,91 vitrification, 84 history of, 4-5 hypothetical solution, 13 introduction, 24 mechanism of action, 5, 8 movement pathway, 18 oocyte cryopreservation slow cooling, 10, 121, 122 vitrification, 134, 139, 140, 145 ovarian tissue cryopreservation, 191 ovary (whole) cryopreservation, 242-243 permeability, 16-17, 20, 21 phase diagram for, 12-14, 13 selection of, 16 slow-freezing cryopreservation, 99, 191 sperm cryopreservation, 41

Index

CPAs (cryoprotectants) (cont.) structures, 6 toxicity, 7 assessment issues, 31 cryobiological property, 16 factors in, 7, 31-32 risk reduction, 13-14, 32, 134, 145 vitrification, 99, 148, 160 concentration in, 14, 84 without CPAs, 41 zona pellucida manipulation, 102 see also non-penetrating cryoprotectants; penetrating cryoprotectants cryobanking, 213-214 disease transmission risk, 139 donor eggs, 175 long-term, 72 ovarian stem cells, 213-214 ovarian tissue, 213-214 pronuclear stage embryos, 77 safety considerations, 72, 84 sperm, 46 storage containers, 90 transportation to, 213 cryobiology, 1-4, 7-8 cryodamage, 16 in cryopreservation protocols, 24 in developmental stages, 21-22 cryodamage, 4, 24 and outcomes, 90 blastocysts, 71, 99-100 cryobiology of, 16 egg banks and, 169-170 embryos, 16, 70-71 membrane permeability and, 10 - 11oocytes, 16, 120-121 testing for, 79-80 Cryoleaf, 132, 134 Cryolock, 132, 134, 172-173 in thawing protocol, 173 Cryoloop, 92, 106, 132, 133 blastocyst vitrification, 98 cooling/warming rates, 135-137 oocyte vitrification, 133 sperm vitrification, 48 cryopreservation, 8 cooling rate and danger zones, 13 indications for, 1, 24, 78-80 in nature, 1 options for, 190-191 outcomes, 90 slow cooling, history, 10 stress of, 79-80 timing in, 77 toxicity avoidance, 32

water/CPA movement pathways, 20 - 21cryopreservation straws, 133, 135-137 see also cut standard straws (CSS) cryoprotectants see CPAs cryostability evaluation, 158 cryostorage, see cryobanking Cryotip, 98, 132, 133 Cryotop, 106, 132, 133 blastocyst vitrification, 98, 100, 102 cooling/warming rates, 135-137 MII spindle maintenance, 124-125 oocyte vitrification, 134 outcomes, 102 crystal formation, 4 cultural issues in cryopreservation, 174-175, 251 culture containers, in vitro follicle culture, 204 culture duration, clinical efficacy, 127 culture media, 204-206, 205,208 culture system blastocysts, 96-97 follicles, 204-206, 206-207 cumulus-oocyte complexes, 146 cut standard straws (CSS), 158, 165 blastocysts, 163-164 cooling/warming rates, 135–137 development of, 158-159 illustrated, 158, 159 cyclophosphamide, 189, 190 cytoplasm, fluorescent staining, 206 cytotoxic chemotherapy, see gonadotoxic chemotherapy danger zones, cooling rate and, 13 dehydration, 1-2, 122 intracellular, 12 role of CPAs, 121 slow-cooling method, 121, 122 in whole organ cryopreservation, 243 developmental ability, zygote initial score, 162 developmental delay, ART babies, 182 developmental stages choice for cryopreservation, 90, 96 cryopreservation procedures, 16 for embryo transfer, 96 permeability changes, 16-22, 18, 20,21 dextran, 30 diffusion (facilitated), see channel

diffusion diffusion (simple), 16, 17 early embryos (mouse), 20 oocytes (mouse), 18, 20

dilution procedure, 141 dimethyl sulfoxide (DMSO), 19-20, 25 - 26aquaporin 3 transport, 18 aseptic vitrification, 158 blastocyst cryopreservation, 163-164 combined CPAs, 13-14, 139 cooling/warming rates, 89, 157 embryo cryopreservation, 68, 76, 139 oocyte cryopreservation, 139, 145, 160 properties of, 5-6 structure, 6 toxicity, 31 vitrification, 139, 160, 163-164 directional freezing, 244-245 disaccharides, 28, 29 disease transmission risk, vitrification, 138-139 DMSO, see dimethyl sulfoxide DNA integrity follicle viability, 206-207 sperm cryopreservation, 48, 54 doctors, influence of, 249 donor programs donation defined, 175 egg donation, 171 oocyte vitrification, 169-170, 174, 175-176 egg bank, 172 protocol, 172-173 restrictions on, 175 semen cryopreservation, 48 sperm cryopreservation, 46 donor-recipient synchronization, 169 donor selection, 170 criteria, 47, 170 for recipient, 173 medical tests, 171 double fertility preservation, 213 early embryo cryopreservation, 20-21 see also cleavage stage embryo cryopreservation early-stage follicle culture, 205-206 ectopic pregnancy, 179, 183 EG, see ethylene glycol egg banks cryopreservation, 169-170 donations, 174, 175 egg donation, see oocyte donation egg yolk-citrate buffer, 41 ejaculation, induced, 53 see also masturbation ejaculatory dysfunction, electroejaculation therapy, 48-49

electroejaculation, 48-49, 53

electron microscopy grids, 132, 133

Index

blastocyst vitrification, 97 cooling/warming rates, 135-137 embryo vitrification, 106 oocyte vitrification, 133, 134 embryo biopsy, see biopsy, embryos embryo carrier devices, 106, 132-135, 133 aseptic vitrification, 107 effectiveness, 134-135 hermetically sealed, 106-107 non-aseptic, 107 see also Cryoleaf; Cryolock; Cryoloop; Cryotop; cut standard straws; electron microscopy grids; Vitrisafe embryo cryopreservation, 70, 72, 76 see also cleavage stage embryo cryopreservation; pronuclear stage embryo cryopreservation cooling rate, 77 CPAs in, 16-17, 20-21, 26, 139 cryodamage, 16 day 3 and day 4, 90-92 ethical issues, 144, 250-252 evaluation, 158 gonadotoxic chemotherapy, 68, 190-191 treatment delay, 190-191, 251 in ART, 67-68, 89, 93, 102 legal issues, 114 methodology, 68-69 outcomes, 69-72, 79-80, 90, 163 embryo survival, 68 prognostic factors, 163 religious objections, 114 slow-freezing technique, 92 volume change measurement, 17 vs. fresh embryos, 102 vs. oocyte cryopreservation, 114, 128 water movement in, 16-17, 20-21 embryo cryopreservation (animals), 76 non-penetrating CPAs, 29, 30 penetrating CPAs, 28 embryo cryostorage, indefinite, 255 embryo donation, 89, 109, 254-255 embryo selection for cryopreservation, 69-70, 90, 91 for transfer, 70, 71-72, 93 developmental stages, 90, 93 endometrial receptivity, 111 grading, 147-148 oocyte numbers thawed, 126 oocyte quality, 123 embryo transfer (ET) biopsied embryos, 81 cleavage stage vs. blastocysts, 96, 102 day 6 stage blastocysts, 100-101

fresh vs. cryopreserved, 80, 102 in vitro fertilization and, 67, 102 oocytes GV stage vs. mature, 116, 147-148 pronuclear stage, 80-81 pronuclear vs. blastocysts, 81-82, 96 pronuclear vs. early cleavage stages, 82 embryonic stem cells, 62, 254-255 embryos cleavage rate, 54 disposal, 254 embryonic stem cell harvesting, 254-255 implantation, 81 ownership, 254-255 permeability changes, 21 embryos (rodent) 1-cell, 17, 20 2-cell, 16, 17, 20 4-cell, 17 CPA permeability, 18, 20 non-penetrating CPAs, 30-31 penetrating CPAs, 26-27, 26 water movement pathway, 17-18 endocrine activity, see hormone levels endometrial preparation, 109 for blastocyst transfer, 101, 109, 111 for embryo transfer, 81, 173 ovarian tissue transplantation, 226 endometriosis, 152, 190 environmental contamination, vitrification risk, 138-139 environmental factors, in transplantation results, 220 enzymatic digestion, follicular isolation, 195, 196, 201-204 epidermal growth factor, 205 epididymal sperm, 52, 54 equilibration, 7 cooling rate and, 137 donor egg bank protocol, 172-173 in pre-freeze stage, 76-77 slow-freezing technique, 91 vitrification, 92, 100 oocytes, 137 146 equilibration solution (ES), 140, 146 estradiol, 207, 226 estrogen levels, 207, 224 estrogen-progesterone administration, 221 ethanamide, see acetamide 1,2 ethandiol, see ethylene glycol (EG) ethanol, 28 ethical issues embryo donation, 254

fertility cryopreservation, 248-253, 253-255 long-term cryostorage, 72, 255 ovarian transplantation, 195-196 sperm cryopreservation, 43 testicular tissue cryopreservation, 62 young cancer patients, 62-63, 248, 249-250 ethylene glycol (EG), 27 aseptic vitrification, 158 blastocyst vitrification, 160, 164 combined CPAs, 13-14, 139 embryo cryopreservation, 139 mechanism, 18, 19 oocyte cryopreservation, 139, 145 vitrification, 139, 146, 160 properties of, 6-7 structure, 6 toxicity, 7, 122 exposure time, CPA toxicity, 31-32 extracellular ice formation, 12, 120-121 extracellular matrix, 204 facilitated channel diffusion, see channel diffusion fallopian tube cryopreservation, 237-238 families, future effects of donor programs, 175 Family Law Reform Act (1969) UK, 249 family lineage preservation, 249 female age, see maternal age fertility impairment, xi fertility preservation, xi fertility restoration future possibilities, 62 ovarian tissue transplantation, 223-225, 226 SSC transplantation, 59-61 fertilization cryopreservation complications, 42 - 43frozen-thawed oocytes, 126, 147 frozen-thawed sperm, 54 fetal hearts, assessment, 126 fetal ovaries, follicle culture, 201, 207, 208 fetal sacs, assessment, 126 fibroblast growth factor (bFGF), 205 Ficoll, 30 fluorescent microscopy, 206 follicle-stimulating hormone (FSH) after ovarian tissue graft, 193, 224, 226 in culture media, 205

Index

follicles

apoptosis in culture, 206–207 ischemic loss in transplantation, 194 isolation techniques enzymatic digestion, 195, 196, 201-204 mechanical, 201-204 ovarian tissue sources, 201, 206 ultrastructure, 206 follicular culture, 208-209 difficulties, 195, 208-209 evaluation methods, 206-207 hormone production, 207 outcomes, 207-208 publications on, 202-213 follicular development assessment, 206 ischemia and, 219-220 ovarian tissue grafts, 194, 226 sites, 191, 220, 225 ovarian transplantation, 245 follicular viability determination, 206 whole ovary cryopreservation, 195, 235-236, 237 whole ovary transplantation, 234 folliculogenesis after ovarian tissue graft, 193 control of, 200-201 forearm, graft sites, 223-225 formamide, 26 fragmentation, in embryos, 163 freeze-thaw damage, see cryodamage freezing devices, programmable, 235, 237 freezing point, CPAs in lowering, 5 freezing rate, see cooling rate freezing, cell damage in, 1-2 fresh vs. frozen embryo transfer, 80, 102 friend/relative, gamete donation, 169 FSH, see follicle-stimulating hormone functional evaluation follicular growth, 207 of oocytes, 123 functional lifespan ovarian tissue transplantation, 233, 241-242 ovary (whole) cryopreservation, 245 fungi, cryostorage risk, 139 galactose, 28 gamete donation, program options, 169

see also embryo donation; oocyte donation; sperm donation gamete donors genetic screening, 47 health screening, 139 gametes cryobank storage, 213-214 informed consent for minors, 250 ownership and disposition, 253-254 gene expression, cultured follicular growth, 207 genetic abnormalities continuation, 253 oocyte donation needed, 169 genetic screening, see pre-implantation genetic diagnosis (PGD) genital surgery, 40 genitourinary health checks, 47-48 germ cells, 59 germinal vesicle (GV) oocytes, 116-117, 160, 213 aseptic vitrification, 160, 213 cryopreservation difficulties, 144 immature oocyte, 116-117 transportation to cryobank, 213 vitrification, 117, 148, 160 glass state, 11, 13-14 glass transition temperature (Tg), 2–3 glial cell-derived growth factor, 61 glucose, 28 glycerol, 27 embryo cryopreservation, 76, 139 gamete cryopreservation, 139 in water movement pathway, 18-19 oocyte cryopreservation, 145 properties of, 5 sperm cryopreservation, 41 structure, 6 toxicity, 31-32 gonadal dysgenesis, 169 gonadal tissue cryopreservation, 253-254 gonadotoxic chemotherapy autoimmune disorders, 151-152 embryo cryopreservation, 68 in childhood, 57-58 sperm cryobanking, 40, 46, 51 toxicity of individual agents, 189, 190 treatment planning, 40, 58-59,233 gonadotoxic radiotherapy, see radiotherapy gonadotropin, 221, 226 grafted ovarian tissue, 218 growth differentiation factor, 200-201, 207 growth factor-supplemented media, 204, 207 GV oocytes, see germinal vesicle (GV) oocytes gynecological malignancy, 190

health outcomes, children of fertility preservation, 127-128, 253 heart cryopreservation, 245 heart malformations, babies of fertility preservation, 180, 183 heat transfer ultra-rapid warming, 159 whole ovary, 242-243, 244-245 hematological disease malignant, 151, 190, 226-229 non-malignant, 190 hemi-straw embryo carrier, 107, 132 cooling/warming rates, 135-137 hepatitis A/B/C, 42, 84 HEPES-buffered media, 139 heterotopic transplantation ovarian tissue, 193-194, 218-219, 223 sites, 220, 223-225 histological analysis follicular development, 206 ovarian tissue, 215, 226 Hodgkin's lymphoma oocyte vitrification, 151 ovarian tissue cryobanking, 192, 229 homosexual couples, 174-175 hormone levels after ovarian tissue graft, 192, 193, 194, 219, 224 monitoring, 224, 226 sites, 218-219 after whole ovary transplantation, 234 in vitro follicle growth, 207 hormone stimulation, oocyte harvesting, 171, 184 hormone therapy, endometrial preparation, 101, 109, 147, 173 Human Fertilisation and Embryology Act (HFEA) UK, 249, 250, 253 human immunodeficiency virus (HIV), 42, 47, 84 hyaluronan, 31 hydraulic conductivity (or coefficient), 10 hydrostatic pressure, polyvinyl alcohol and, 13 hypothalamic gonadotropin-releasing hormone pulse generator, 200-201 ice formation, 1-2, 10-11 extracellular, 12, 120-121 intracellular, 7, 12, 24-25, 120-121 optical differences, 12 prevention by CPAs, 24-25, 28,

120-121

Index

solubility and, 4 temperature change rate, 11, 120 - 121ice, nature of, 2 ICSI, see intracytoplasmic sperm injection imaging, cancer patients, 228 imide CPAs, see formamide: methanamide implantation rates after embryo cryopreservation, 71 - 72after oocyte cryopreservation, 126, 127 day 6 stage blastocysts, 100-101 success prediction, 71-72, 162 in vitro culture follicles, 201-204, 207-209, 212-213 ovarian cortical tissue, 201-204 ovarian tissue, 214, 215-216 SSC expansion, 61 zygote post-thawing integrity and, 161 in vitro fertilization (IVF) blastocyst cryopreservation, 95 congenital abnormality, 179-181 cryopreservation in, 24 embryo transfer, 67 embryo selection, 70 outcomes vs. ICSI, 80-81 embryos, 89 donation, 254 multigestation pregnancy reduction, 67-68, 76 ownership, 254 oocyte cryopreservation, 120, 125 outcomes, 102, 125 ovarian hyperstimulation syndrome risk, 78-79 sperm donation, 48 sperm harvesting, 49, 51 surfactants, 30 in vitro maturation (IVM) blastocyst vitrification, 108-110, 111 follicules, 206 GM stage oocytes, 148 GV stage oocytes, 116-117, 144-145, 213 oocyte vitrification, 148-150, 151 primordial follicles, 200-201, 195 infectious disease/infective agents cryostored embryos, 72 embryo vitrification, 84 oocyte vitrification, 138-139 sperm cryopreservation, 42 sperm donor screening, 47-48 see also aseptic vitrification

embryo donation, 254 IVF patients, 108-109 treatment, 72 young boys, 63-58, xi see also cancer patients; gonadotoxic chemotherapy; premature ovarian failure informed consent donor egg programs, 175 donor sperm, 47 embryo cryopreservation, 72, 251 long-term cryostorage, 72 oocyte cryopreservation, 252 ovarian cryopreservation, 195-196 ovarian tissue cryopreservation, 252-253 parental consent, 251 sperm cryobanking, 43, 248-249 two-stage process, 250 validity, 72 young patients, 62, 250, 252-253 inhibin B levels, 224, 226 insect breeding, sperm cryopreservation, 39-40 insulin, 205 insulin-like growth factor (IGF), 205 intracellular dehydration, 12 intracellular ice formation, 7, 12, 24-25, 120-121 intracytoplasmic sperm injection (ICSI) congenital abnormality, 179-181 donor program, 173 oocyte cryopreservation, 116 semen samples for, 58 sperm cryopreservation, 48, 53-54 sperm retrieval, 51 testicular sperm, 54 testicular tissue, germ cells from, 58,59 vs. IVF in outcomes, 80-81 intrauterine insemination, 40, 42 ipsigeneic germ cell transplantation, 59 ischemia follicular development following, 219-220 ovarian tissue transplantation, 233, 241-242 ovary transplantation, 194 ovary vitrification, 236 isolated follicles early-stage, culture, 205-206 enzymatic digestion, 195, 196 primordial, in vitro maturation, 195 IUI (intrauterine insemination), 40, 42

infertility,

IVF, see in vitro fertilization IVM, see in vitro maturation Kit ligand, 201, 205 laboratory fertilization, risks in, 184 lactose, non-penetrating CPA, 29 large volume samples, freezing, 244-245 late pregnancy loss, 179, 183 latent heat release, 243 legal aspects embryo cryopreservation, 72, 78 posthumous disposal of biomaterials, 253-254 sperm cryopreservation, 43 liquid nitrogen (LN₂), 41 contact with, 106, 134, 158 contamination risk, 98-99, 106, 138 - 139osmotic stress reduction, 12 storage in, 146-147 tissue destruction by, 1 liver cryopreservation, 245-246 LN₂, see liquid nitrogen long-term storage ART outcome, 184 ethical issues, 251 low birthweight, ART and, 184 luteinizing hormone (LH), 200-201 macromolecules, CPAs, 30-31 magnetic separation immunoassay analysis, 207 malignancy, see cancer patients malignancy residual disease, see minimal residual disease (MRD) maltose, 29 mannose, 29 masturbation, 41, 58, 248-249 maternal age ART outcomes, 80, 125-126, 178 late pregnancy loss, 179 oocyte donation needed, 169 maternal ill-health, ART outcomes, 184 McGill Cryoleaf efficacy of, 148, 148-150 illustrated, 146, 147 oocyte thawing, 147-148 oocyte vitrification, 144-145 vitrification, 146 McGill protocols, 147-148, 150-153 mechanical isolation, of follicles, 201-204 medical practitioners, influence of, 249 meiotic spindle, 145, 148, 172

CAMBRIDGE

Cambridge University Press 978-0-521-51778-2 - Fertility Cryopreservation Ri-Cheng Chian and Patrick Quinn Index More information

Index

membranes, see cell membranes menstrual cycle, natural, 101 mental competence, in consent, 250, 251, 252-253 MESA (microsurgical epididymal sperm aspiration), 41, 42-43, 52 metaphase II, see MII methanamide, 26 methanol, 27 methyl sulfoxide, see dimethyl sulfoxide microbial contamination risk, in vitrification, 158 microdissection for testicular sperm extraction (Micro-TESE), 53 microscopy frozen-thawed oocytes, 123-124 MII spindle maintenance, 125 microsurgical epididymal sperm aspiration (MESA), 41, 42-43, 52 microtubule depolimerization, 172 microvacuolization, 124 MII oocytes ovarian tissue autotransplantation, 194 rapid freezing, 157-158 spindle damage, 122, 124-125 MII oocytes (mouse) aquaporin 3 expression, 17-18 CPA permeability, 18-20 water movement pathway, 17 minimal residual disease (MRD) monitoring, 226, 228 risk ovarian tissue grafts, 252 testicular tissue cryopreservation, 250 use of SSCs, 62 whole ovary grafts, 195 minimum volume cooling protocol, 172-173 miscarriage, 178-179, 182 molality, 3 molarity, 3 monoethylene glycol (MEG), see ethylene glycol monosaccharides, 28-29 MOPS-buffered media, 139 moral objections to egg donation, 175 to embryo cryopreservation, 251 morulae (mouse) CPA permeability, 18, 19, 20 cryopreservation procedures, 16 water movement pathways, 17, 18 morulae cryopreservation, 21 motherhood postponed, 153

131-132, 174-175, 178 oocyte vitrification, 142 mother-to-daughter oocyte donation, 152-153 mouse developmental stages, 16-22 MRD, see minimal residual disease multigestation pregnancies, 67, 181, 184 avoidance, 67-68, 89 legal restrictions on, 76 rates of, 181 Multi-Thermal-Gradient (MTG) device, 235, 237, 244-245 musculoskeletal abnormalities, 180, 183 neonatal outcomes, ART babies, 149-150, 182, 184 neovasculation, ovarian tissue grafts, 233 nitrogen see also liquid nitrogen slush device, 132-134 non alkylating agents, 57-58 non-aseptic vitrification, 108-109, 160 non-biological carriers, 54 non-malignant systemic diseases, 40 non-penetrating cryoprotectants, 26, 28-31,76 in thawing, 78 slow-cooling cryopreservation, 121, 122 vitrification, 140 non-penetrating polymer, 13 non-vitrifying solutions, 108, 109-110 nucleation, ice formation, 2 nucleoli, zygote quality, 161 obstetric outcomes oocyte cryopreservation, 132, 178, 184 singleton pregnancies, 181-182 OHSS, see ovarian hyperstimulation syndrome oligoathenoteratozoopermia, 42 oligozoospermia, 48, 57-58 oncology, see cancer patients oocyte cryopreservation, 69, 114-115, 117, 128 advantages of, 144 cell membrane permeability, 16-17 concerns about, 120 cooling rate, 77 CPA permeability, 20-21, 30, 139 damage during, 16, 31-32

oocyte cryopreservation, 114,

developmental stage, 116-117 history, 114-115, 121-122, 132 indications for, 120, 131-132, 157-158 legal issues, 251-252 new developments, 122-123 outcomes effectiveness, 125, 191 implantation rate, 126 in cancer patients, 251-252 perinatal risks, 178, 184 pregnancy, 182-184, 185 ownership and disposition, 253-254 publications, 126 quality, 123, 124–125 MII spindle in, 125 ovarian tissue graft sites, 220 pronuclei in, 158 safety, 127-128, 184 slow cooling, 10, 115-116, 120-121, 172 slow cooling vs. vitrification, 145, 148 social and cultural effects, 174-175 treatment delay in cancer patients, 251 unfertilized, 69-70 volume change measurement, 17 water movement, 20-21 young patients, 251-252 see also oocyte vitrification oocyte donation, 114, 169-170, 174 donor selection, 170-171 donor stimulation, 171 mother-to-daughter, 152-153 oocyte vitrification, 172 restrictions on, 175 oocyte retrieval in unstimulated menstrual cycle, 144-145 McGill Cryoleaf protocol, 148-150, 151 transvaginal follicular aspiration, 171 oocyte thawing in donor program, 173 McGill Cryoleaf protocol, 147 oocyte vitrification, 115, 116, 131-132, 142, 153 advantages/disadvantages, 146, 172 at GV stage, 160 breast cancer patients, 151 cooling rate, 134 CPAs in, 84, 145 developments in, 144-145 donor programs, 169-170, 171, 172, 175-176 advantages, 172 outcomes, 174 history, 145

Index

McGill Cryoleaf protocol, 144-145, 146 outcomes, 175 neonatal, 149-150 protocols compared, 127 risks, 178 success rates, 137 principles of, 145 solutions for, 139-141 oocyte-derived factors, 200-201 oocytes evaluation of, 123-124, 161, 206 folliculogenesis, 200-201, 208-209 in vitro aging, 127 membrane permeability, 10-11, 21 nucleus counting, 206 numbers thawed, 126 reserve, 189 see also germinal vesicle oocytes oocytes (animal) polymer CPAs, 30 sugars as CPAs, 29 oocytes (mouse) CPA permeability, 18-20, 26-27 non-penetrating CPAs, 30 water movement pathway, 17 oophorectomy, for ovary cryopreservation, 237, 238 open pulled straw (OPS), 132, 133 cooling/warming rates, 135-137 in CSS development, 158 oocyte vitrification, 133 organ transplantation, 241 orthotopic transplantation ovarian tissue, 192-193, 218-219 surgical techniques, 223 sites for, 220, 223-225 osmosis, 4 osmotic pressure, extracellular, 4 osmotic shock, prevention, 28 osmotic shrinkage, 16 osmotic stress, 12, 162-163 osmotic swelling, cryodamage, 16 outcomes, aseptic vitrification, 109 classic technique, 115, 116 embryo cryopreservation developmental stages at, 81-82, 91 - 92live birth rates, 72, 81-82 embryos implantation, 81 transfer, 80-81 GV stage oocyte cryopreservation, 116-117 in vitro culture post-thawing, 161

McGill Cryoleaf vitrification protocol, 148, 148-150 obstetric, adverse, 182 oocyte cryopreservation, 115-116, 125, 132 protocols compared, 127 oocyte vitrification, 116, 137, 175 in donor program, 174 ovarian tissue transplantation, 193 slow-freezing technique, 83, 91-92, 115-116 sperm donation, 48 success rates embryo transfer, 80-82 oocyte vitrification, 137 sucrose in slow-freezing solutions, 115-116 vitrified vs. slow-freezing technique, 83 see also pregnancy outcomes ovarian cortex, 200, 206, 213 ovarian cortical tissue culture, 206 primordial follicle activation, 207 two-step system, 205-206 follicles from, 201 handling, 222 in vitro culture, 201-204 ovarian function, 200-201 ovarian hyperstimulation syndrome (OHSS) embryo cryopreservation need, 68, 78-79,89 risk in stimulation protocols, 79, 144-145, 175 ovarian neoplasm, 151 ovarian stem cells, 213-214 ovarian stimulation, 67, 171, 184 in breast cancer, 151 outcomes, 81-82 ovarian tissue, 201, 208, 252 ovarian tissue cryobanking, 213-214 indications for, 221-222 outcomes, 214-216 procedure safety, 226-229 storage protocol, 221-222, 226 transportation, 213 ovarian tissue cryopreservation, 189, 196,242 cancer patients, 191, 252-253 disadvantages, 144 for transplantation, 219-220 histological analysis, 216 in vitro culture, 214 indications for, 190 minimal residual disease risk, 144, 229

ownership and disposition, 253 - 254protocol, 191, 214-216, 222 young patients, 252-253 ovarian tissue transplantation, 191-195, 218, 219-220 autotransplantation, 191-195, 227 clinical cases, 227 cortical pieces, 192 endocrine monitoring, 224 functional lifespan, 225, 233, 241-242 heterotopic, 193-194 history, 218-219, 220 indications for, 218, 221-222 ischemia, 241-242 orthotopic, 192-193 patient evaluation, 222 patient monitoring, 226 protocols/procedures, 223 publications, 218 sites for, 218-220, 220, 223 success factors surgical techniques, 223 xenografting, 191 ovarian vasculature, graft sites, 225 ovary (whole) as graft site, 223 culture, 204 heat transfer, 242-243 ovary (whole) cryopreservation, 233-234, 238, 242 animal models, 234-236, 245-248 directional freezing, 244-245 follicular viability, 237 heat transfer difficulties, 242-243, 244-245 human studies, 238 pregnancies after, 215 protocols, 195, 236-238 recent developments, 242 ovary (whole) transplantation, 194–195, 220, 241, 245 ovary (whole) with vascular pedicle cryopreservation, 234-236 advantages in, 233 animal models, 233-236 CPA perfusion, 194 transplantation, 194-195, 234 parental consent

embryo cryopreservation, 251 oocyte cryopreservation, 252 ovarian tissue cryopreservation, 252–253 sperm banking, 249 patient evaluation, pre-transplant, 222

Index

patient monitoring, post-transplant, 226 pelvic imaging, 226 pelvic peritoneum, graft sites, 223-225 penetrating cryoprotectants, 4-7, 24 - 28embryo cryopreservation, 76, 139 oocyte cryopreservation, 121, 139, 145 oocyte vitrification, 140 percutaneous epididymal sperm aspiration (PESA), 41, 52 permeability, see cell membrane permeability PG, see 1,2-propanediol pH difference, physiological solutions, 139 phase diagram for CPAs, 12-14 phosphate-buffered saline (PBS), 123, 139 physiological solutions, in vitrification, 139 plasma membranes, see cell membranes polarized light microscopy, 125 Polscope, 125 polycystic ovary syndrome (PCOS), 109, 144-145, 179 polyethylene glycol (PEG), 30 polymerase chain reaction, real-time 207, 227 polymers, 13, 30-31, 145 polyols, 27-28 polysaccharides, 28, 29-30 polyvinyl alcohol, 31 polyvinylpyrrolidone, 30-31 posthumous disposal of biomaterials, 253-254 posthumous sperm retrieval, 51 post-insemination time, embryo transfer outcomes, 80 postpubertal females, 250-252 postpubertal males, 248-249 pre-antral follicles, 204, 207-208 pre-freeze stage, 76-77 pregnancy outcomes embryo cryopreservation, 89, 90, 95 embryo implantation and, 81 hormone replacement for support, 147 oocyte cryopreservation, 182-184, 185 ovarian cryopreservation, 215 ovarian tissue cryobanking, 214-216 ovarian tissue transplantation, 192-193, 220

pregnancy rates blastocyst stages, 160, 164 cryopreservation complications, 42 - 43embryo stages, 81-82, 83 oocyte cryopreservation, 127 oocytes, 251-252 pronuclear integrity and, 163 testicular sperm, 54 vitrification protocols, 83, 148-150, 160 pre-implantation genetic diagnosis (PGD), 79, 89, 102 blastocyst cryopreservation, 102 embryo biopsy, 82 pronuclear stage cryopreservation, 79 pre-implantation stage, embryo cryopreservation protocol, 69 premature ovarian failure (POF) chemotherapy-induced, 189, 196 oocyte donation needed, 169 ovarian cryobanking need, 221 ovarian tissue cryobanking need, 190, 218 radiotherapy-induced, 189-190 prepubertal boys, 59-61, 249-250 prepubertal girls, 252-253 prepubertal ovaries, follicle source, 201 preterm delivery, ART and, 184 primordial follicles activation of, 204-205 assessment, 222 in vitro culture, 195, 200, 204-205, 207, 208 in vivo development, 200-201 progesterone, 207 PROH, see 1,2-propanediol pronuclear integrity, 161, 163 pronuclear membranes, 161 pronuclear stage embryo cryopreservation, 69-70, 76-78, 157-158 comparative studies, 81-82, 96 cooling rate, 77 cryodamage, 70 developmental stage and outcomes, 81-82 freezing stage, 77, 78 indications for, 78-80 morphological evaluation, 161-163 scoring system and outcome, 161, 162, 163 selection for, 77 thawing, 77 timing in, 77 vitrification, 82-84

embryo transfer, 82 pronuclear zygotes, see pronuclear stage embryo cryopreservation pronuclei, oocyte and embryo evaluation, 158 1,2-propanediol (PROH, propylene glycol), 18, 27 combined CPAs, 13-14, 139 embryo cryopreservation, 68-69, 76,139 oocyte cryopreservation, 122, 145 oocyte vitrification, 139 properties of, 7 structure, 6 toxicity, 31-32, 122 vitrification solutions, 139, 146 in water movement pathways, 20 propylene glycol, see 1,2-propanediol protein macromolecules/polymers, 30,33 psychogenic anejaculation, 48-49 publications on carrier devices, 134-135 on in vitro follicular culture, 202-213 on oocyte cryopreservation, 126, 132 on vitrification, 131 quality of life cancer survivors, xi cancer treatment planning, 58-59 childhood cancer management, 58 radioimmunoassay, 207 radiotherapy, gonadotoxicity, 40, 189 - 190raffinose, 29 rapid freezing,157-158, 173 see also ultra-rapid cooling; vitrification real-time polymerase chain reaction, 207, 227 recipient preparation, see endometrial preparation recrystallization, in thawing period, 243-244 rehydration, during warming, 121 rejection, of graft, 241 religious issues, embryo disposal, 255 research, embryo donation for, 254-255 retrograde ejaculation, semen collection, 49 revascularization, grafted ovarian tissue, 191, 219

pronuclear vs. early cleavage stages,

safety carrier devices, 138-139 embryo cryopreservation, 72 embryo vitrification, 84 oocyte cryopreservation, 132 ovarian tissue cryobanking, 226-229 ovarian transplantation, 195-196 Sage IVF Vitrification Warming Kit, 141 secondary follicle culture, 200 semen cryopreservation boys, 58-59 donor program, 47, 48 seminiferous tubules sperm retrieval from, 52-53 spermatogenesis in, 60 SSC transplantation, 59-61 semipermeable membranes, water transportation, 4 sequential culture, for blastocysts, 96-97 Sertoli cells, 60, 61 serum in culture media, 204 sexually transmitted infections, 47 shared egg donation, 169 shrinkage (artificial), of blastocele, 99-100, 101 simple diffusion, see diffusion (simple) single embryo transfer (SET), 67, 68 single women, 174-175 single-phase culture, 96-97 singleton pregnancies, 181 slow-freezing cryopreservation, 10, 157 blastocysts, 69, 97, 99 CPA phase diagram, 12-14 donor program, 48 embryos, 69 cleavage stage, 70 days 3/4, 91–92 pronuclear stage, 76-77, 83 thawing, 92 Multi-Thermal-Gradient system, 244-245 oocytes, 115-116, 120-121, 127 osmotic stress reduction, 12 ovarian tissue, 191, 215 solutions for, 115-116 sperm, 42, 41 testicular tissue, 59 time factors, 131 vitrification compared, 83, 99, 102, 127 whole organs, 243 whole ovary, 237, 242-243 whole ovary with vascular pedicle, 234-236

social effects, oocyte crypreservation, 174-175 social reasons for fertility preservation sperm cryopreservation, 39, 40 see also motherhood postponed sodium-free freezing media, 126 classic technique, 116 MII spindle maintenance, 124-125 slow-freezing protocols, 122-123 solubility, 3-4 solutes concentration in cryoinjury, 4 in aqueous solutions, 3 membrane permeability to, 10-11 solution effects, in cryopreservation, 12, 122-123 solutions, in vitrification, 134, 146 solvents, 3-4 sperm abnormal, 42 collection, 41 informed consent for, 248-249 techniques, 51-53, 54, 58 morphology, 42 motility, 42 sperm (animal) cryopreservation breeding programs, 39-40 CPAs, 26 damage by, 32 non-penetrating monosaccharides, 29, 28 polymers, 31 sugars, 28-30 penetrating alcohols, 27, 28 formamide, 26 sperm cryobanking ethical considerations, 248-249 in China, 46-48 sperm cryobanks sperm cryopreservation, 40, 43, 62-63 adverse effects, 42-43 boys with cancer, 58-59 clinical applications, 40 complications, 42-43 contraindications, 42 donor programs, 46, 48 history, 39, 95 ownership and disposition, 253-254 protocols, 40-41 quality of sperm, 42, 48, 54 quantity of sperm, 42 retrieval techniques, 51-53 electroejaculation, 48-49 surgically retrieved, 51, 53 viability, 42 vitrification, 41, 84

sperm donation cryopreservation in, 46, 48 follow-up results, 48 sperm donors, selection/screening, 46 - 48spermatids, in ICSI, 58 spermatocytes, in ICSI, 58 spermatogenesis restoration, 61-62 SSCs in. 60 spermatogonial stem cells, see SSC spermatozoa, vitrification, 160 spinal cord injury, 48–49, 53 spindle malformation, 144, 145 SSC (spermatogonial stem cells), 59, 62-63 in spermatogenesis, 60 in vitro culture, 61 isolation and purification, 61-62 testicular tissue cryopreservation, 61-62 transplantation, 59-61 stage-specific markers, follicular growth, 206–207 stem cells, ovarian, 213 see also embryonic stem cells; SSC spermatogonial stem cells stimulation protocols, oocyte donation, 171 storage, see cryobanking straws, see cryopreservation straws; cut standard straws (CSS) subcutaneous sites, for grafts, 223-225 subfertility, male, 42 sucrose, 29, 140 blastocyst vitrification, 164 clinical efficacy, 124, 126-127 concentrations, 122 embryo cryopreservation, 68 in CPA mixture, 139 MII spindle maintenance, 124-125 oocyte cryopreservation, 115-116, 122, 123, 145 oocyte vitrification, 140 osmotic stress reduction, 12 slow-freezing solutions, 12, 115-116, 122 sodium-free freezing media, 123 sugars, 28-30 sulfoxide cryoprotectant, see dimethyl sulfoxide supercooling, 2-3, 99, 243 supplements to culture media, 204-206 surgery on male genitalia, 40 ovarian tissue grafts, 223

Index

surgically retrieved sperm, 41, 51, 53 survival rates childhood malignancies, 57 cryopreserved oocytes, 127, 147, 174 systemic autoimmune rheumatic diseases, 151-152 systemic lupus erythematosus, 151-152 SYTOX dye, 206-207 temperature and equilibration time, 7 in CPA permeability, 12 in CPA toxicity, 7, 31-32 measurement, 2 nature of water and, 2 solubility and, 3-4 transportation to cryobank, 213 water movement pathways, 16, 17 temperature gradient cooling rate, 243 cooling rate and ice formation, 11 directional freezing, 244-245 glass transition (Tg), 2-3in cooling and warming, 12 in slow-cooling method, 121 ultra-rapid warming, 159 testicular sperm, 52-53, 54 testicular sperm aspiration (TESA), 52 testicular sperm extraction (TESE), 52 - 53testicular tissue ownership and disposition, 253-254 sperm retrieval from, 52-53 SSC numbers, 61-62 testicular tissue (animals), 60-61 testicular tissue cryopreservation, 63 - 58ethical issues, 62, 249-250 for prepubertal boys, 40, 59, 249-250 problems with, 61-62 SSC transplantation, 59-61 Tg (glass transition temperature), 2-3 thawing aseptic vitrification and, 110 blastocysts, 100, 101, 108 donor program, 173, 174 embryos, 77-78, 91-92 non-aseptic vs. aseptic cooling, 108 oocytes, 126, 147-148, 174 recrystallization in, 243-244 slow-freezing technique, 91 vitrification and, 100, 174 whole ovary with vascular pedicle, 234, 235 thawing medium, 147 thermal gradient, see temperature gradient

tissue handling, ovarian cryopreservation, 222 tools, see embryo carrier devices toxicity, see CPAs, toxicity transforming growth factor-β superfamily, 200-201 transmission electron microscopy, 206 transplantation environmental factors in results, 220 history, 241 see also heterotopic transplantation; orthotopic transplantation; ovarian tissue transplantation; ovary (whole) transplantation transportation, 84, 213 transvaginal follicular aspiration, 171 treatment delay, cancer patients, 251 trehalose, 29 TUNEL labeling, 206 Turner syndrome, 152-153, 169 two-stage consenting process, 250 two-step culture system, 205-206, 208 two-step vitrification, 21

UK

consent for minors, 249, 250 oocyte cryopreservation, 253 sperm donor anonymity, 47 ultra-rapid cooling, 106, 108, 111 ultra-rapid warming, 159 urinary tract inflammations, 49 urogenital reconstructive surgery, 51 USA consent for minors, 249, 250 oocyte cryopreservation, 252 sperm donor screening/testing, 47 uterine dysfunction, after radiotherapy, 189

vacuolization of embryos, 163 of oocytes, 174 vascular pedicle, intact ovary and, 194-195, 216 vascular surgery, development of, 241 vascular transplantation, whole ovary, 194-195 Vero cells, co-culture, 95 vibratory stimulation, 53 viral agents, in cryostorage, 139 viscosity, 14 vitamin E, antioxidant treatment, 220 Vitmaster, 132-134 vitreous state, 11 vitrification, 131 advantages, 11, 146

aneuploidy, 148 aseptic, 106-107 blastocysts, 95, 97-99 aseptic, 106-107 CPAs, 21, 99 slow-freezing compared, 99 water movement, 21 closed systems, 84 CPA damage, 12–14 CPA movement, 20-21 developments in, 157-158 disadvantages, 146 embryos, 69 CPAs, 20-21 day 3 and day 4, 92 pronuclear stage, 77, 82-84 water movement, 20-21 equilibration in, 7 GV stage oocytes, 117 ice crystal prevention, 11 McGill Cryoleaf procedure, 146 morulae, 21 one-step treatment, 21 oocytes, 115, 116, 127 ovarian tissue, 215 probability of, 11, 131 process of, 2, 3 pronuclear stage embryos, 69-70, 83 publications on, 131 relationship of conditions for, 14 sperm, 41 for donor program, 48 two-step treatment, 21 variables influencing effectiveness, 11 vs. ice crystals, optical differences, 12 vs. slow freezing, 102 water movement, 20-21 whole ovary with vascular pedicle, 234-236, 235, 131 see also embryo carrier devices; vitrification carrier devices vitrification carrier devices, 92, 131, 146 blastocysts, 97, 100 oocytes, 132-135 vitrification solutions for oocytes, 139-141 McGill Cryoleaf protocol, 146-147 McGill Cryoleaf vitrification, 146 scientific disclosure, 140 vitriplug hemi-straw embryo carrier, 107 Vitrisafe, 107, 110 volume changes, measurement, 16

Index

warming after slow cooling, 121 aseptic vitrification, 159, 160 carrier devices and, 135–137 phase diagram for CPAs, 12–14 Sage IVF Vitrification Warming Kit, 141 vitrification protocols, 92 conditions for, 14 effectiveness, 137–138 solutions, 140–141 water glass transition, 2–3 intracellular, 1 reduction by CPAs, 26 nature of, 2 properties in cryopreservation, 24 water movement pathways, *see* channel diffusion; diffusion (simple); osmosis water permeability, 10–11, 16, 21 whole ovary cryopreservation, *see* ovary (whole) cryopreservation

xenogeneic germ cell transplantation, 59 xenografting, 191, 219–220 young boys, fertility cryopreservation, 58, 249–250 young cancer patients, *see* cancer patients, young patients young men, SSC transplantation, 59–61 zona pellucida

breach, 138, 164 hardening, 174 manipulation, 80–81, 102 zygotes cryodamage, 70 initial score, 162 selection, 71