

CONTENTS

NOTE TO THE READER	11
LIST OF PARTICIPANTS	13
PREAMBLE	
Background	19
Objective and Scope	19
Selection of Topics for Monographs	20
Data for Monographs	21
The Working Group	21
Working Procedures	21
Exposure Data	22
Evidence for Carcinogenicity in Humans	23
Studies of Cancer in Experimental Animals	27
Other Relevant Data	29
Summary of Data Reported	30
Evaluation	32
References	36
GENERAL REMARKS	39
SOLAR AND ULTRAVIOLET RADIATION	
1. Exposure data	43
1.1 Nomenclature	43
1.1.1 Optical radiation	43
1.1.2 Quantities and units	45
1.1.3 Units of biologically effective ultraviolet radiation	46
1.2 Methods for measuring ultraviolet radiation	47
1.2.1 Spectroradiometry	47
1.2.2 Wavelength-independent (thermal) detectors	48
1.2.3 Wavelength-dependent detectors	48
1.3 Sources and exposures	49
1.3.1 Solar ultraviolet radiation	50
(a) Measurements of terrestrial solar radiation	54
(b) Personal exposures	57
1.3.2 Exposure to artificial sources of ultraviolet radiation	58
(a) Sources	58
(i) Incandescent sources	58
(ii) Gas discharge lamps	59

CONTENTS

(iii) Arc lamps	59
(iv) Fluorescent lamps	59
(v) Metal halide lamps	59
(vi) Electrodeless lamps	59
(b) Human exposure	60
(i) Cosmetic use	60
(ii) Medical and dental applications	63
(iii) Occupational exposures	66
(iv) General lighting	70
(c) Regulations and guidelines	70
(i) Cosmetic use	70
(ii) Occupational exposure	71
2. Studies of cancer in humans	73
2.1 Solar radiation	73
2.1.1 Nonmelanocytic skin cancer	73
(a) Case reports	73
(i) Studies of xeroderma pigmentosum patients	73
(ii) Studies of transplant recipients	73
(b) Descriptive studies	74
(i) Host factors	74
(ii) Anatomical distribution	74
(iii) Geographical variation	75
(iv) Migration	76
(v) Occupation	76
(c) Cross-sectional studies	77
(d) Case-control studies	83
(e) Cohort studies	86
(f) Collation of results	91
2.1.2 Cancer of the lip	93
(a) Descriptive studies	93
(i) Geographical variation	93
(ii) Occupation	94
(b) Case-control studies	94
2.1.3 Malignant melanoma of the skin	95
(a) Case reports	95
(b) Descriptive studies	95
(i) Sex distribution	95
(ii) Age distribution	95
(iii) Anatomical distribution	96
(iv) Ethnic origin	96
(v) Geographical variation	96
(vi) Migration	99
(vii) Socioeconomic status and occupation	99

CONTENTS

(c) Case-control studies	100
(i) Australia	100
(ii) Europe	102
(iii) North America	106
(d) Collation of results	113
(i) Total sun exposure: potential exposure by place of residence	113
(ii) Biological response to total sun exposure	113
(iii) Total sun exposure assessed by questionnaire	115
(iv) Short periods of residence implying high potential exposure	115
(v) Occupational exposure	115
(vi) Intermittent exposure	115
(vii) Sunburn	122
2.1.4 Malignant melanoma of the eye	122
(a) Case reports	122
(b) Descriptive studies	125
(i) Ethnic origin	125
(ii) Place of birth and residence	125
(iii) Occupation	127
(iv) History of skin cancer	127
(c) Case-control studies	127
2.1.5 Other cancers	130
2.2 Artificial sources of ultraviolet radiation	130
2.2.1 Nonmelanocytic skin cancer	130
2.2.2 Malignant melanoma of the skin	130
2.2.3 Malignant melanoma of the eye	134
2.3 Premalignant conditions	134
2.3.1 Basal-cell naevus syndrome	134
2.3.2 Dysplastic naevus syndrome	134
2.4 Molecular genetics of human skin cancers	135
2.4.1 <i>ras</i> Gene mutations	135
2.4.2 p53 Gene mutations	135
3. Studies of cancer in animals	139
3.1 Experimental conventions	139
3.1.1 Species studied	139
3.1.2 Wavelength ranges	139
3.1.3 Measured doses	140
3.1.4 Protocols	140
3.2 Broad-spectrum radiation	141
3.2.1 Sunlight	141
3.2.2 Solar-simulated radiation	142
3.2.3 Sources emitting UVC, UVB and UVA radiation	142
3.3 Sources emitting mainly UVB radiation	144
3.3.1 Mouse	144

CONTENTS

3.3.2	Rat	146
3.3.3	Hamster	146
3.3.4	Guinea-pig	146
3.3.5	Fish	146
3.3.6	Opossum	146
3.4	Sources emitting mainly UVC radiation	147
3.4.1	Mouse	147
3.4.2	Rat	148
3.5	Sources emitting mainly UVA radiation	148
3.6	Interaction of wavelengths	150
3.6.1	Interaction of exposures given on the same day	150
3.6.2	Long-term interactions	151
3.7	Additional experimental observations	151
3.7.1	Tumour types	151
3.7.2	Dose and effect	153
3.7.3	Dose delivery	154
3.7.4	Action spectra	154
3.7.5	Pigmentation	155
3.8	Administration with known chemical carcinogens	155
3.8.1	Administration with polycyclic aromatic hydrocarbons	156
	(a) 3,4-Benzo[<i>a</i>]pyrene	156
	(b) 7,12-Dimethylbenz[<i>a</i>]anthracene	156
3.8.2	Administration with other agents with promoting activity	157
	(a) Croton oil	157
	(b) 12- <i>O</i> -Tetradecanoylphorbol 13-acetate	158
	(c) Benzoyl peroxide	158
	(d) Methyl ethyl ketone peroxide	159
3.9	Interaction with immunosuppressive agents	160
3.10	Molecular genetics of animal skin tumours induced by ultraviolet radiation	161
4.	Other relevant data	163
4.1	Transmission and absorption in biological tissues	163
4.1.1	Epidermis	163
	(a) Humans	163
	(b) Experimental systems	164
	(c) Epidermal chromophores	165
	(d) Enhancement of epidermal penetration of ultraviolet radiation	166
4.1.2	Eye	166
	(a) Humans	166
	(b) Experimental systems	166
4.2	Adverse effects (other than cancer)	167
4.2.1	Epidermis	167
	(a) Humans	167
	(i) Erythema and pigmentation (sunburn and suntanning)	167

CONTENTS

(ii) Pigmented naevi	169
(iii) Ultrastructural changes	170
(iv) Keratosis	172
(v) Photosensitivity disorders	172
(b) Experimental systems	173
(c) Comparison of humans and animals	174
4.2.2 Immune response	175
(a) Humans	175
(i) Contact hypersensitivity (allergy)	175
(ii) Lymphocytes	176
(iii) Infectious diseases	177
(iv) Photosensitive diseases	177
(b) Experimental systems	177
(i) Contact hypersensitivity	177
(ii) Delayed hypersensitivity to injected antigens	179
(iii) Immunology of ultraviolet-induced skin cancer	180
(iv) Transplantation immunity	180
(v) Infectious diseases	181
(vi) Human lymphocytes <i>in vitro</i>	182
(c) Comparison of humans and animals	182
4.2.3 Eye	183
(a) Humans	183
(i) Anterior eye (cornea, conjunctiva)	183
(ii) Lens	183
(iii) Posterior eye	183
(b) Experimental systems	184
(i) Anterior eye	184
(ii) Lens	184
(iii) Posterior eye	184
(c) Comparison of humans and animals	184
4.3 Photoproduct formation	185
4.3.1 DNA photoproducts	185
(a) Cyclobutane-type pyrimidine dimers	185
(b) Pyrimidine-pyrimidone (6-4) photoproducts	186
(c) Thymine glycols	187
(d) Cytosine damage	188
(e) Purine damage	188
(f) DNA strand breaks	188
(g) DNA-protein cross-links	189
4.3.2 Other chromophores and targets	189
(a) Chromophores	189
(b) Membranes	190

CONTENTS

4.4	Human excision repair disorders	191
4.4.1	Xeroderma pigmentosum	191
4.4.2	Trichothiodystrophy	192
4.4.3	Cockayne's syndrome	193
4.4.4	Role of immunosuppression	193
4.5	Genetic and related effects	194
4.5.1	Humans	194
(a)	Epidermis	195
(i)	Broad-spectrum ultraviolet radiation, including solar simulation	195
(ii)	UVA radiation	196
(iii)	UVB radiation	196
(iv)	UVC radiation	197
(b)	Lymphocytes	198
(i)	Broad-spectrum ultraviolet radiation	198
(ii)	UVA radiation	199
(iii)	UVB radiation	199
4.5.2	Experimental systems	199
(a)	DNA damage	199
(b)	Mutagenicity	200
(c)	Chromosomal effects	202
(d)	Transformation	203
(e)	Effects of cellular and viral gene expression	204
5.	Summary of data reported and evaluation	217
5.1	Exposure data	217
5.2	Human carcinogenicity data	218
5.2.1	Solar radiation	218
(a)	Nonmelanocytic skin cancer	218
(b)	Cancer of the lip	219
(c)	Malignant melanoma of the skin	219
(d)	Melanoma of the eye	220
(e)	Other cancers	220
5.2.2	Artificial sources of ultraviolet radiation	220
5.2.3	Molecular genetics of human skin cancers	221
5.3	Carcinogenicity in experimental animals	221
5.4	Other relevant data	222
5.4.1	Transmission and absorption	222
5.4.2	Effects on the skin	222
5.4.3	Effects on the immune response	222
5.4.4	DNA photoproducts	223
5.4.5	Genetic and related effects	223
5.5	Evaluation	227
6.	References	229

CONTENTS

SUMMARY OF FINAL EVALUATIONS	281
GLOSSARY OF TERMS	283
Appendix 1. Topical sunscreens	285
1. General	285
2. Protective effects	286
2.1 Against DNA damage	286
2.2 Against acute and chronic actinic damage	286
2.3 Against immunological alterations	286
2.4 Against tumour formation	286
3. Adverse effects	287
3.1 Acute toxicity	287
3.2 Chronic toxicity	287
3.3 Reduced vitamin D synthesis	287
4. References	288
CUMULATIVE INDEX TO THE <i>MONOGRAPHS</i> SERIES	291

NOTE TO THE READER

The term 'carcinogenic risk' in the *IARC Monographs* series is taken to mean the probability that exposure to an agent will lead to cancer in humans.

Inclusion of an agent in the *Monographs* does not imply that it is a carcinogen, only that the published data have been examined. Equally, the fact that an agent has not yet been evaluated in a monograph does not mean that it is not carcinogenic.

The evaluations of carcinogenic risk are made by international working groups of independent scientists and are qualitative in nature. No recommendation is given for regulation or legislation.

Anyone who is aware of published data that may alter the evaluation of the carcinogenic risk of an agent to humans is encouraged to make this information available to the Unit of Carcinogen Identification and Evaluation, International Agency for Research on Cancer, 150 cours Albert Thomas, 69372 Lyon Cedex 08, France, in order that the agent may be considered for re-evaluation by a future Working Group.

Although every effort is made to prepare the monographs as accurately as possible, mistakes may occur. Readers are requested to communicate any errors to the Unit of Carcinogen Identification and Evaluation, so that corrections can be reported in future volumes.