UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

March 23, 1987

SAB-EC-87-025

OFFICE OF
THE ADMINISTRATOR

Honorable Lee M. Thomas
Administrator
U. S. Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

Dear Mr. Thomas:

The Science Advisory Board's Stratospheric Ozone Subcommittee has completed its review of EPA's risk assessment document entitled An Assessment of the Risks of Stratospheric Modification and is pleased to transmit its final report to you.

The Subcommittee carried out an independent evaluation of the assumptions, conclusions and interpretations used by EPA in assessing the existing scientific information related to stratospheric ozone modification. The Subcommittee also advised EPA on the thoroughness and balance of its treatment of particular scientific issues, noting areas of omission as well as areas emphasized in the assessment document, and reviewing EPA's characterization of scientific uncertainties.

EPA's draft assessment document represents an extensive effort to develop an integrated risk assessment, based upon currently available scientific information, to ascertain the potential threat to the stratosphere posed by a continued growth world-wide of emissions of chlorofluorocarbon compounds (CFCs). The Subcommittee generally finds that EPA had done a commendable job in the body of the report of assembling the relevant scientific information, although the Subcommittee has many recommendations for improving the document. The uncertainty in future CFC emissions has been characterized in the EPA draft as encompassing a range of 0 to 5% for annual emissions growth, with 1-4% as the most likely portion of the range. The Subcommittee recommends that EPA present the 2.5% growth rate as one of a series of illustrative "what-if" scenarios, rather than as a most likely case. The revised Executive Summary adopts this advice.

Depletion of the ozone column can increase ultraviolet radiation (UVB), resulting in an increase in nonmelanoma skin cancer. Available scientific evidence suggests that melanoma may also increase as a result of increased ultraviolet radiation. There may be other significant health effects, in addition to adverse impacts on plants and aquatic organisms. Information on the impacts of increased ultraviolet radiation on plants and aquatic organisms is extremely limited. The Subcommittee believes that the potential for adverse impacts on plants and aquatic organisms is sufficiently large to warrant high priority for further investigation.

The Subcommittee believes that the information summarized in the draft risk assessment supports the conclusion that the possible impact of CFCs on the stratosphere should be considered a high priority issue for further investigation and analysis by EPA and other Federal agencies, and provides a scientific basis for the recently initiated international efforts to address this problem.

The Subcommittee reviewed the first draft of the entire assessment document during its initial meeting. Following that session, using comments received from members of the Subcommittee and the public, EPA staff rewrote the Executive Summary. This revision was resubmitted in time for the Subcommittee's second meeting. The Subcommittee's report, therefore, provides scientific advice on the revised Executive Summary and the first draft of the individual chapters of the assessment document. The Subcommittee members have not seen revisions to the individual chapters and request that EPA staff transmit the revised chapters and any further revision of the Executive Summary for their individual review once this task is completed. Following this individual member cycle of review, the Chair and Vice Chair will transmit a letter to EPA noting the extent to which the Agency has responded to its scientific advice.

We appreciate the opportunity to participate in the evaluation of this important public health and environmental issue. We request that the Agency formally respond to the scientific advice provided in the attached report.

Sincerely,

Margaret Kripke

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Chair
Stratospheric Ozone Subcommittee
Science Advisory Board

Norton Nelson

Norton Nelson
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Executive Committee
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SAB-EC-87-025

REVIEW OF EPA'S

AN ASSESSMENT OF THE RISKS OF STRATOSPHERIC MODIFICATION

BY THE

STRATOSPHERIC OZONE SUBCOMMITTEE

SCIENCE ADVISORY BOARD

U. S. ENVIRONMENTAL PROTECTION AGENCY

March, 1987

U. S. ENVIRONMENTAL PROTECTION AGENCY

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I. Introduction

A. Scope and Charge of the Subcommittee's Review

On January 9, 1986 EPA's Assistant Administrator for Air requested the Science Advisory Board to evaluate the Agency's assessment of the risks of stratospheric modification. Specific questions posed to the Board included reviewing and assessing EPA's treatment of the scientific issues of concern (e.g., long term trends in trace gases, atmospheric science, and health and ecological effects from ozone depletion).

On January 31, 1986 the Science Advisory Board Executive Committee accepted this request and authorized the formation of a Stratospheric Ozone Subcommittee to conduct the review. The Subcommittee's role was to carry out an independent evaluation of the assumptions, conclusions and interpretations developed or used by EPA in assessing the existing scientific information related to stratospheric ozone modification. The Subcommittee also advised EPA on the thoroughness and balance of its treatment of particular scientific issues, noting areas of omission as well as areas emphasized in the assessment document, and reviewing EPA's characterization of scientific uncertainties.

The Subcommittee's primary effort was directed at examining the scientific logic used by EPA in its efforts to synthesize the available scientific literature. While it conducted a chapter-by-chapter review of the assessment document, the Subcommittee recognizes that not all of the issues discussed in each chapter are of equal public health or environmental importance.

At no time did the Subcommittee believe that its role was to assist EPA in writing the assessment document. Instead, it has offered specific technical advice for improving the scientific quality of the document. EPA

must then decide whether to accept or not accept this advice. The Subcommittee also construed its role as an advisor rather than as a final approval body that would supervise detailed editorial and factual changes to all sections of the document. The latter role was beyond the Subcommittee's resource capability and was also inconsistent with the role of an advisor performing a timely review.

B. Subcommittee Review Procedures

The Subcommittee met twice in public session in Washington, D. C., on November 24-25, 1986 and January 26-27, 1987. Notice of each meeting was published in the Federal Register. During its meetings the Subcommittee heard presentations from EPA staff and had the opportunity to provide both verbal and written criticisms of the material submitted for review. In addition, the Subcommittee made time available for members of the public to present verbal and written comments on the scientific adequacy of EPA's assessment document. Participating organizations included the Alliance for a Responsible CFC Policy, Chemical Manufacturers Association, Dupont Corporation, Environmental Defense Fund and Natural Resources Defense Council, as well as individual members of the scientific community. These presentations, and the interactions between the Subcommittee and EPA staff, resulted in a wide ranging scientific dialogue whose aim was to solicit information and facilitate the Subcommittee's effort to achieve consensus on the major issues for which it was advising EPA.

The Subcommittee reviewed the first draft of the entire assessment document during its initial meeting. Following that session, using comments received from members of the Subcommittee and the public, EPA staff rewrote the Executive Summary. This revision was resubmitted

in time for the Subcommittee's second meeting. The Subcommittee's report, therefore, provides scientific advice on the revised Executive Summary and the first draft of the individual chapters of the assessment document.

Following its first meeting, the Subcommittee drafted an interim report that summarized its major thoughts at that stage of the review. This was expanded and updated at the second meeting. Final editing of the report was carried out by mail and telephone conversations. The Science Advisory Board's Executive Committee approved the report by mail on February 25, 1987.

The Subcommittee members have not seen revisions to the individual chapters and request that EPA staff transmit the revised chapters and any further revision of the Executive Summary for their individual review once this task is completed. Following this individual member cycle of review, the Subcommittee Chair and Vice-Chair will transmit a letter to EPA noting the extent to which the Agency has responded to its scientific advice.

II. General Comments and Conclusions

EPA's draft document represents an extensive effort to develop an integrated risk assessment based upon currently available scientific information to ascertain the potential threat to the stratosphere posed by a continued growth world-wide of emissions of chlorofluorocarbon (CFCs) compounds. The Subcommittee generally finds that EPA has done a commendable job of assembling the relevant scientific information in the body of the document, although the Subcommittee has many specific recommendations for improving the treatment of particular scientific issues and characterizing scientific uncertainties.

EPA states the uncertainty in future CFC emissions as encompassing a range of 0 to 5% for annual emissions growth, with 1-4% as the most likely scenario within the range. The Subcommittee recommended that EPA

present the 2.5% growth rate as one of a series of illustrative "what-if" scenarios, rather than as a most likely case. The revised Executive Summary adopts this advice.

Calculations with one and two dimensional atmospheric models indicate that continued CFC annual emissions growth of 2.5% or above could lead to depletion of global column ozone by several percent within the next forty years and much higher reductions in subsequent decades if this rate of CFC emissions growth continues. Ozone reduction will continue, albeit at a slower rate even if the rate of emissions becomes constant. The retention time of CFC gases in the atmospheric is decades to centuries, so that the CFC buildup cannot be quickly reversed once it has occurred. The impacts of ozone depletion will be largest at high latitudes and at high elevations of the stratosphere, although changes in ultraviolet radiation will be determined by column ozone (total ozone in a column through all levels of the atmosphere).

Changes in CFC gases interact with changes in greenhouse gases (CO_2, N_2O, CH_4) in determining changes in ozone concentrations. The impact of CFC emissions on ozone concentrations may be even larger if growth in these greenhouse gases is reduced from current trends. In addition, CFC gases have a potential impact on global climate, although this impact appears to be only about 20 percent of that anticipated from changes in CO_2, N_2O, and CH_4. The impact on climate of changes in ozone concentration appears to be small by comparison.

Depletion of the ozone column can increase ultraviolet radiation (UVB), resulting in an increase in non-melanoma skin cancer. Available scientific evidence suggests that melanoma may also increase as a result of increased ultraviolet radiation. There may be other significant health

effects, in addition to adverse impacts on plants and aquatic organisms. Information on the impacts of increased ultraviolet radiation on plants and aquatic organisms is extremely limited. The Subcommittee believes that the potential for adverse impacts on plants and aquatic organisms is sufficiently large so that further research of these areas should receive high priority.

The Subcommittee believes that the information summarized in the draft risk assessment supports a conclusion that the possible impact of CFCs on the stratosphere should be considered a high priority issue for further investigation and analysis by EPA and other Federal agencies, and provides a scientific basis for the recently initiated international efforts to address this problem.

The draft document represents a useful step toward communicating the applicable scientific information to decision makers, but decisions on CFC regulations will require further analysis of the regulatory options beyond the analyses presented in the draft risk assessment.

The Subcommittee has reviewed, but has not evaluated in detail, the quantitative projections of health and other impacts associated with growth in CFC emissions that are contained in the draft risk assessment. The integrating model appears to be a useful vehicle for summarizing the implications of alternative assumptions regarding emissions, atmospheric response to CFCs and other trace gases, implications for changes in ultraviolet radiation, and consequent changes in the incidence of skin cancer in the U. S. population during the lifetimes of the current population and those individuals born during the next century. Some other impacts (e.g., economic costs of damage to polymeric materials, soybeans as an example of crop loss, and anchovy loss as an example of

population impact for a sensitive aquatic species) are included in the quantitative analysis using the integrating model. Many potentially important impacts are not included since the information to support quantitative projections of these impacts is not yet available.

The draft document makes a reasonable attempt to characterize uncertainties in scientific knowledge and in the assumptions for growth of CFC emissions. The Subcommittee recommends further efforts to state assumptions more explicitly and to more clearly characterize the limits of currently available information.

The draft document is long and repetitive and, yet, some critical information is not readily available. As an example, much of the discussion of CFC emissions' projections in Chapter 3 presents results with little information on underlying assumptions and data. EPA has taken these results from contractor reports that are not available in the peer reviewed literature. It is highly desirable that the final document, with its appendices, be self-contained and reasonably complete. Additional appendices summarizing contractor work and documenting more fully the integrating model of Chapter 17 may, therefore, be needed.

In summary, the entire draft document represents a good first effort to summarize an exceedingly complex set of issues, and the Subcommittee commends EPA for the progress achieved to date.

III. Specific Comments on the Revised Executive Summary

The Subcommittee believes the Executive Summary is extremely important because it is likely to receive the most attention and will be used for a variety of purposes, including domestic regulatory decision making and international negotiations. For this reason, the Executive Summary needs to be accurate and explicit, and provide a balanced overview of the

content and conclusions of the entire assessment document. The Subcommittee spent most of the time at its second meeting reviewing and discussing this portion of the document. It reached the following conclusions and recommendations:

1. The revised Executive Summary represents a marked improvement over the original version. Our major criticism of the original Executive Summary was its failure to reflect accurately and objectively the content of the individual chapters in the report. EPA staff have made significant progress in correcting this problem.

2. Additional revisions are still needed to reach the necessary level of accuracy, balance and clarity. The Subcommittee recommends that both the findings summary and the chapter summaries be organized into subsections to facilitate their presentation. All long headings in the chapter summaries should be shortened to a brief sentence. The document should also present an outline or diagram illustrating the atmospheric processes involved in the creation and destruction of ozone. Many specific suggestions for improvement of the Executive Summary were discussed with or submitted in writing to Mr. John Hoffman for incorporation into a second revision of the Executive Summary.

3. Although the Executive Summary is now more accurate and objective in describing the information and conclusions of the entire document, statements interpreting the results for non-scientists, and indications of the relative importance of the issues considered, need to be provided. For example, each point made in the Executive Summary appears to be given equal weight, when clearly, the issues differ widely in terms of their potential significance. Specific recommendations for addressing this problem include:

a) EPA should clearly and forcefully state that, by the time it is

possible to detect decreases in ozone concentration with a high degree of confidence, it may be too late to institute corrective measures that would reverse this trend.

b) Predictions of ozone depletion derived from atmospheric models are consistent, in most instances, with actual measurements of ozone concentration, even though these measurements are subject to considerable uncertainty.

c) Both the relative state of knowledge, and our ability to obtain new information in the immediate future are different for each area summarized in the document. For some issues, it will take decades to obtain missing information whereas, on others, rapid progress can be predicted. However, this variation in the information base should not preclude recognition of the potential problem of ozone depletion or making decisions that address the problem. Decisions can and should be made, even in the face of current uncertainties.

d) The Executive Summary should provide a sense of proportion and balance among the scientific issues evaluated, particularly in presenting the findings of the document. Clearly, the consequences of ozone depletion could be major for some effects, even though the amount of information available is small. A large amount of information does not necessarily imply greater importance compared to the effects on which little information is available. EPA should attempt to prioritize the effects that might result from ozone depletion and to distinguish between effects that are of greater or lesser consequence on a global scale. The following table is provided to illustrate the Subcommittee's view of the relative significance and state of knowledge for each of the effects summarized in the report:

Effect	State of Knowledge	Potential Global Impact
Skin Cancer	Moderate to high	Moderate
Immune System	Low	High
Cataracts	Moderate	Low
Plant Life	Low	High
Aquatic Life	Low	High
Climate Impacts*	Moderate	Moderate
Tropospheric O_3 and H_2O_2	Moderate	Low
Polymers	Moderate	Low

* Contribution of O_3 to climate changes, including sea level rise

A principal use of this table could be as a guide to research planning, especially in conducting research for effects where current knowledge is low and potential global impacts are high. Such a table is, however, an imperfect guide for allocating research dollars, and is subject to change as new information becomes available.

The Subcommittee does not know, based on current knowledge, whether effects with a potential global impact designated as "high" with a state of knowledge designated as low will occur but, if such effects are experienced, they could be significant.

e) The Executive Summary should devote less emphasis to climate change and its effects, such as sea level rise. It should focus, instead, on the contribution of changes in ozone concentration to climate modification, rather than reviewing all the radiatively-active gases that affect climate. We recognize that the ozone depletion and global warming (greenhouse) issues are linked; nonetheless, the emphasis in this document should be placed on stratospheric, rather than tropospheric processes.

IV. Specific Comments on Individual Chapters

Chapter 1: Goals and Approach

This short introductory chapter was not formally reviewed. The

Subcommittee endorses the statement of purpose for the risk assessment.

Chapter 2: Stratospheric Perturbants: Past Changes in Concentrations

This chapter on past changes in concentration of stratospheric perturbant gases is generally acceptable as written. The discussion of CO should be strengthened, and additional discussion of volcanic gases and trace gas lifetime may be appropriate. The more accurate term "steady-state" should be used instead of "equilibrium." EPA may wish to move the discussion of atmospheric response dynamics (page 2-21 to page 2-25) into Chapter 5, or elsewhere, as a part of the discussion on modeling stratospheric response to perturbant gases.

Chapter 3: Emissions of Ozone Modifiers

At the Subcommittee's request, EPA developed a set of "what-if" scenarios to explore the range of reasonable outcomes for future CFC world production. In addition to cases with constant growth rates in the range of 0-5% annually, EPA considered cases with near-term growth followed by a leveling off and decrease in production levels. EPA should seek assumptions and additional insights to characterize the CFC uses that may cause high future demand for CFCs, such as widespread use of air conditioning and refrigeration in developing nations, as opposed to describing scenarios only in terms of annual growth rate. Characterization of the potential for substituting in various CFC uses may provide a means of developing insight on the relative likelihood of the production scenarios. Given the importance of the uncertainty in future world CFC production levels on the projected timing and magnitude of stratospheric ozone changes, further research on CFC uses and their alternatives is highly desirable.

Chapter 4: Future Emissions and Concentrations of Trace Gases

As in Chapter 3, a central case for the growth of CO_2 and other

greenhouse gases may project a misleading impression of current ability to predict the future evolution of atmospheric conditions. The EPA responded to the Subcommittee's suggestion to explore a set of scenarios and a range of plausible future conditions. However, insights on the potential role of fossil fuel uses, changes in deforestation, and other factors underlying changes in greenhouse gas levels should be described. Uncertainty on non-anthropogenic emissions and resulting uncertainties in the trends for CH_4 and N_2O should be discussed further. This chapter could benefit from extensive rewriting and reorganization.

Chapter 5: Assessment of the Risk of Stratospheric Ozone Modification

The discussion of one dimensional (1-D) models should be condensed, while more discussion of two dimensional (2-D) models and perhaps three dimensional (3-D) modeling approaches would be useful in explaining the current understanding of the complex set of relationships determining ozone levels and climate changes. It is crucial to communicate the extent of predictive power of current models. We recognize the need for improved models that can describe seasonal and regional changes in ozone abundance and the resulting climatic changes.

The Monte Carlo analysis of Stolarski and Douglas indicates that screening sets of variables to combinations that are reasonably consistent with available atmospheric measurement data changes the character of the results as stated in the Executive Summary and the findings of Chapter 5. The discussion on pages 5-88 and 5-93 with Figures 5-57 and 5-58 should become the basis for revising the statement of these results. The choice of material for the chapter summary should be improved. The chapter could benefit by extensive editing and rewriting.

Chapter 6: Climate Change

The Subcommittee judged this to be one of the better written chapters, providing a balanced summary of the available scientific information on climate change. However, the focus of the chapter should be the contribution of changes in ozone concentration from climate modification, rather than a review of all the radiatively-active gases that affect climate. The chapter should place more emphasis on stratospheric, rather than tropospheric processes. Linkages between ozone concentration changes and climate change should be highlighted, and more attention paid to the effect of changes in the vertical distribution of ozone to climate impacts. A separation of direct and indirect effects would be useful. The chapter should focus on the direct effects of ozone on climate, and briefly summarize the indirect effects of trace gases whose concentrations affect both ozone concentration and climate.

The document should define the eddy diffusion coefficient. The discussion of the importance of cloud cover in determining heat balance should be expanded to at least half a page. More discussion of sensitivity analysis and comparison of 1-D and 2-D model results would be appropriate, and some discussion of further research using 2-D models to explore sensitivity issues would be a useful addition to the chapter. Ocean thermal lag is another important issue for determining climate response and could use more discussion. Absolute concentration information should be added to exhibit 6-3.

Chapter 7: Nonmelanoma Skin Cancer

The Subcommittee generally agrees that this chapter is concise, comprehensive, and well written. No deficiencies were noted in the

breadth of the material reviewed in this chapter. The Subcommittee concurs that considerable evidence supports the conclusion that increased UVB would increase the incidence and mortality of nonmelanoma skin cancer. Specific errors in the text were noted and discussed with appropriate staff members.

Points requiring revision or remaining to be addressed in the body of the text are the following:

1. There needs to be a clear statement of the potential impact of increased UVB radiation on mortality from basal cell carcinoma and squamous cell carcinoma.

2. The document should present a discussion of the validity of existing mortality data for nonmelanoma skin cancer and justification for not basing predictions on these data.

3. The action spectra discussed in the chapter should be presented diagrammatically. These include the action spectra for DNA, the modified DNA action spectrum corrected for skin transmission, the RB meter action spectrum, the cutaneous edema action spectrum, and the ereythema action spectrum.

4. The chapter should justifiy the selection of the action spectra used in the calculations.

5. The major problem with this chapter concerns the translation of information within the chapter into statements concerning the expected numbers of additional cancer cases and additional cancer deaths. The Subcommittee requested an addendum that contains a list of the assumptions underlying the calculated increases in cancer incidence and mortality and some indication of the uncertainties contained within these predictions. This addendum was received, and information from it needs to be incorporated into the chapter. The addendum itself should be included in the appendix.

6. The Subcommittee earlier suggested that a range of values for incidence and mortality be utilized that would reflect predicted upper and lower limits of increased UVB exposure, rather than using the central case values. The staff have adopted this suggestion in the revised Executive Summary; it needs to be incorporated in Chapter 7.

Chapter 8: Melanoma

In general, the Subcommittee agrees that this chapter provides a comprehensive analysis of the evidence for and against the role of sunlight and UVB radiation as a contributing factor in the development of cutaneous melanoma in humans. Although there are still many uncertainties concerning the relationship between UVB and melanoma, the weight of current evidence, especially that provided by recent epidemiologic studies, favors the conclusion that increased UVB radiation is likely to increase the incidence and mortality of cutaneous melanoma in humans.

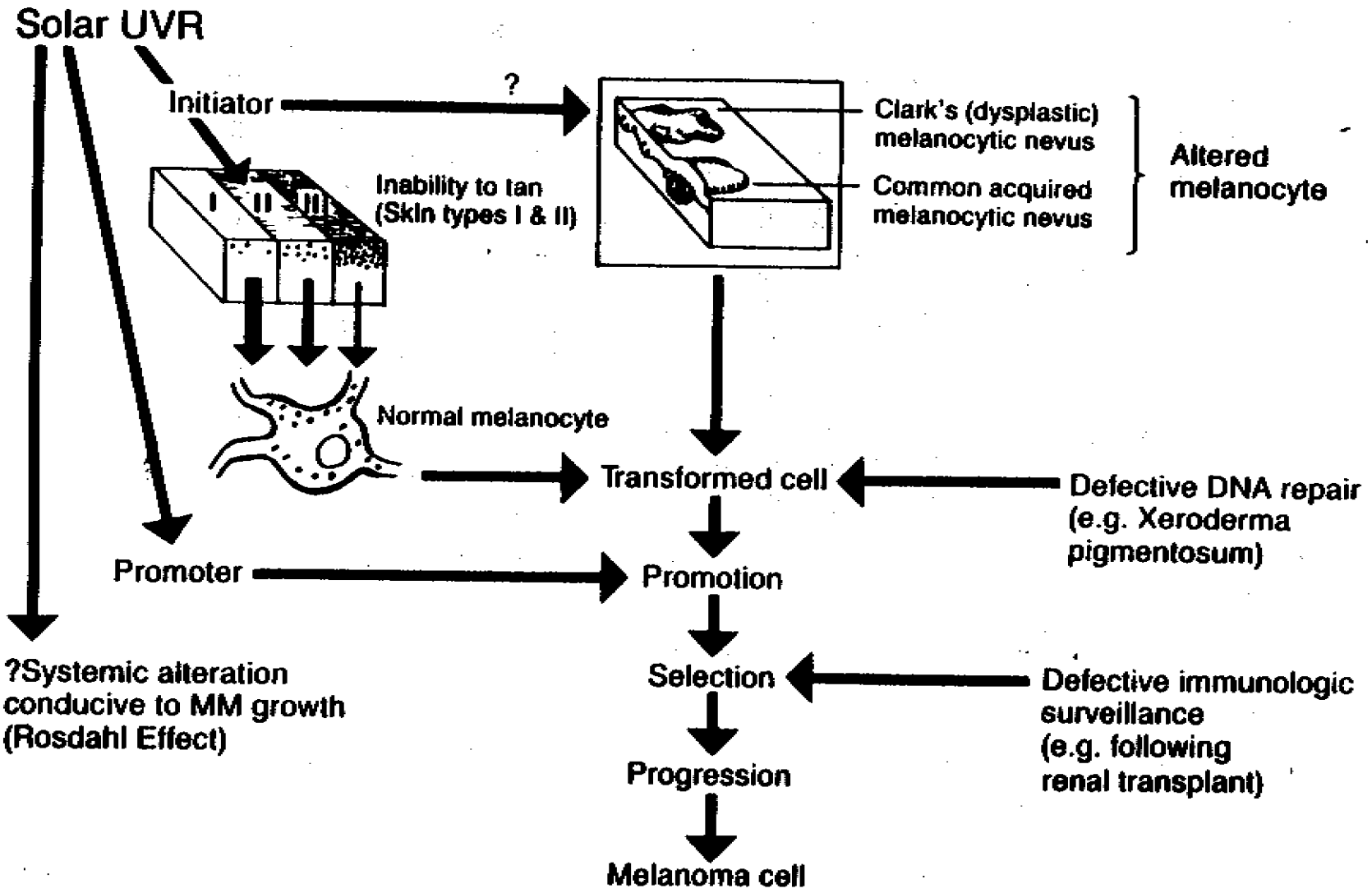
The points remaining to be addressed in this chapter are the following:

1. The staff has provided a statement of the assumptions underlying the calculated increases in the incidence and mortality of melanoma to the Subcommittee, along with justifications for the choice of critical assumptions. This information needs to be incorporated into the chapter.

2. Two concepts need to be addressed in a revised chapter. The first is that UVB radiation could contribute to the incidence and mortality of melanoma without being a direct, causative agent responsible for the transformation of normal melanocytes into cancer cells. The chapter presently considers only the likelihood that UVB is a direct, causative agent that induces cutaneous melanoma (See Figure 1). Second, the chapter should emphasize that the term "melanoma" may actually encompass

FIGURE 1:

Solar Ultraviolet and Malignant Melanoma of the Skin*



*in the white population

a heterogeneous group of disease entities. The possibility that there may be subsets of cutaneous melanoma that are caused, exacerbated or completely unrelated to UVB should be raised in seeking explanations for the obscure relationship between sunlight exposure and melanoma incidence.

3. Material included in this chapter as background information (pp. 8-7 to 8-13) also applies to chapter 7 and should be moved to the beginning of chapter 7 and integrated with the information on action spectra.

4. The statements on the evidence supporting the conclusion that solar radiation is one cause of melanoma (p. 8-4) need to be revised to reflect more accurately the available scientific information.

Chapter 9: Immune System

The Subcommittee concurs with the general summary and conclusions reached in this chapter. Specifically, there is reason to believe that UVB radiation has the potential to modify immune responses in humans and that such modifications could conceivably increase the incidence or severity of some infectious diseases.

In general, the chapter is not well written or well organized, and the Subcommittee made many detailed suggestions concerning appropriate revision of the material to increase both its accuracy and its clarity. However, the suggested revisions would not alter the general conclusions.

The Subcommittee notes several deficiencies in the presentation of the work that require revision. They include:

1. The chapter does not clarify the fact that several different immunologic consequences of UVB irradiation occur, each of which may have a different action spectrum. The available action spectra should be illustrated in a figure.

2. The document should state that UVB exposure produces systemic immunologic changes, as well as local changes within irradiated skin. Restricting consideration to cutaneous infections may represent too narrow a view of the potential consequences of increased UVB irradiation.

3. This chapter should state that, although UVB induced effects on the immune system might contribute to the induction and pathogenesis of skin cancers, this fact is not likely to increase the predicted estimates of increases in skin cancer incidence and mortality.

4. A point needing further emphasis is that most immunologic studies to date have not assessed the effects of long-term, chronic UVB irradiation, but have concentrated on acute effects.

Chapter 10: Cataracts

The chapter on cataracts and other eye disorders is comprehensive and extremely well written. The Subcommittee does not believe that any major study has been omitted in the bibliography, and EPA's assessment of each paper appears to be accurate and balanced.

The findings are accurately stated and succinctly express the legitimate concern that an increase in the flux of the UVB radiation may lead to an increase in cataract incidence around the world. The Subcommittee agrees with these findings and with the Agency's method of presenting them.

Near the end of the chapter, the document emphasizes the effect of UVB radiation on the DNA content of lens cells. This represents an important point that is well treated in the chapter. Researchers have emphasized the effect of irradiation on lens protein, and there has been relatively little discussion of the impact of UVB radiation on lens DNA.

The selection of epidemiologic studies relevant to this issue is correct and well presented. A major limitation which EPA staff may wish to address is that all of the studies are handicapped by the lack of an individual dose meter to measure the ultraviolet exposure on a case by case basis. To date, we have not had such an instrument for use in prospective studies and, therefore, have relied on general radiation levels at different latitudes to estimate the exposures of individuals living at those latitudes.

The discussion of the multifactorial nature of senile cataract formation is accurate. Within one to three years, three major studies of the risk factors in senile cataract formation will be completed in Boston, Parma, Italy and Delhi, India. These studies will also indirectly address the question of ultraviolet exposure and cataract type and severity.

Chapter 11: Terrestrial Effects

The Subcommittee agrees that this chapter presents a balanced overview of available material. The only concern is that the summary statements for this chapter are not balanced and tend to emphasize the negative aspects of the material.

This chapter reviews the available information concerning UVB radiation effects on plants as this relates to the question of potential effects of ozone reduction. Ultraviolet screening tests with agricultural species and cultivars, as well as actual field trials using UV lamps, are described.

Complicating factors such as the appropriate action spectra to use in evaluating ozone change and effects of UV lamp supplementation on the resulting ozone reduction simulations, plant acclimation to enhanced UV

radiation, and interactions with other environmental factors such as drought and carbon dioxide enhancement are discussed. Interpretation of the data and caveats concerning limitations in drawing conclusions from these data are offered.

Overall, the text, considering the length allotted, is reasonably complete and balanced. On the other hand, the summary tends to accentuate results supporting the detrimental effects of ozone reduction. This results in a statement of findings and a summary which are much less balanced than the text itself.

Chapter 12: Aquatic Effects

This is a very thorough, well written chapter. It accurately conveys the extant information on the effects of solar ultraviolet radiation on aquatic systems and explains the difficulties in extending these data to an assessment of the effects of stratospheric ozone reduction. There are a few passages describing laboratory experiments where it is not clear whether the ultraviolet radiation simulating a certain ozone reduction is calculated as that striking the water surface or at some depth in the water. Occasionally, experimental results are not always clearly distinguished from calculated impacts. We believe the issue of large migrations of aquatic populations, e.g. 30° latitude, while illustrative, are unrealistic and could be misleading. These could be eliminated without detracting from the content of the chapter.

As with Chapter 11, assessing the impacts of stratospheric ozone reduction on communities and ecosystems has received less attention and research than issues such as skin cancer. The Subcommittee believes the potential impacts on aquatic and terrestrial food chains, and the potential

effects on the equilibrium of plant and animal assemblages, are just as important as the more intensively studied human effects. This importance needs to be conveyed not only in Chapters 11 and 12 but also in the summaries of these chapters and in the Executive Summary.

Chapter 13: Polymers

The economic analysis on polymer damages is based on the assumption of a small increase in the destruction rate of the polymer material multiplied by a large value for the inventory of material in place. The assumptions of the analysis should be stated more clearly, and the uncertainities in this economic analysis should be highlighted. Discounting future damages should be discussed.

The rate of polymer degradation depends on the actual action spectrum, which is undoubtedly different for each kind of polymer. These spectra should be measured experimentally before any confidence can be placed in the predictions. In many cases, it would be expected that UVB contributes only a small fraction of the total rate and, therefore, the rate would be very insensitive to changes in stratospheric ozone.

The estimates presented by EPA are reasonable in the absence of real data, but the required measurements are not difficult and should be made.

Chapter 14: Potential Effects on Tropospheric Ozone

The document should present a more extensive introduction to the discussion of health and welfare effects of tropospheric ozone. The modeling discussion now found on page 14-11 should be expanded and placed near the front of the chapter. The material on page 9 should be shown as a graph. All three cities should be shown in the figure, page 14-12. The word "smog" is colloquial and should be avoided. The discussion of

the spectral resolution of UV needed for photochemistry should be strengthened. The question of what happens to global tropospheric ozone as UVB increases needs expanding (some discussion of this issue is found in Chapter 5). The limitations of the analysis in this chapter should be stressed more. The effect of CFC emissions reductions on tropospheric ozone should be discussed. Discussion of mass flux and other interactions between the troposphere and stratosphere should be added.

Chapter 15: Sea Level Rise

The Subcommittee reached a consensus that this chapter adequately covers the subject material. However, additional qualifying statements need to be added to the summary statements.

This chapter requires more careful caveats in the summary and findings and references to major reports on sea level rise. Assumptions should be clearly stated. The range of 50-200 cm. of sea level rise seems narrow in view of the many uncertainties on climate change, and the basis for calculating this range should be made explicit. The implications for loss of land of a 1 meter rise might be stated.

More discussion of the economic aspects of sea level rise would be desirable.

Chapter 16 and Appendix B: Impacts of Climate Change

The discussion focuses mainly on North America and Europe. The Subcommittee encourages the staff to present more information on the rice crop and other aspects of agriculture in the developing world. The document should emphasize that uncertainty in the regional effects is substantial. Catastrophic episodes such as floods, droughts, and severe storms may cause much of the damage, and these episodes cannot be reliably predicted.

This chapter represents a compilation of potential consequences of global warming. These synoposes address potential changes in forest and other vegetation distributions, agricultural implications, hydrological cycles and weather effects on morbidity and mortality. This collection of vignettes is, of course, one of only many possible compilations since global warming can have many ramifications.

Chapters 17 and 18: Integrating Model and Results

The objective of the integrating model is to provide a framework within which the implications of alternative assumptions and policies can be identified. The Subcommittee finds this objective commendable and supports EPA's effort to make the assumptions and the logic used in the risk assessment explicit and readily available to interested members of the public. The integrating model appears to be a good vehicle for summarizing the assumptions and calculations described in previous chapters of the risk assessment. An integrating model such as this represents an excellent tool for examining the implications of alternative assumptions--"what if" scenarios--and for investigating the importance of uncertainties in different areas of science for policy and research conclusions.

The logic and implementation of the integrating model as a computer code were the subject of a factfinding meeting of four members of the Subcommittee on January 14, that also included John Hoffman of EPA, and representatives from EPA's contractor, ICF. Prior to the meeting, these Subcommittee members received a listing of input files and the FORTRAN computer code for the model. Other technical documentation for the model does not exist at this time. Based on the written material in Chapter 17 and the discussion at this meeting, the Subcommittee believes that the model, and the results of the model calculations presented in Chapter 18, appear

reasonable. However, the model has not undergone detailed review outside of the EPA/ICF team that developed it, and it has not been documented and placed in a form accessible to outside parties.

The material in Chapters 17 and 18 will need substantial revision as the analysis with the integrating model is revised to meet recommendations from the Subcommittee regarding the Executive Summary and the other chapters. The revised versions of Chapter 17 and 18 should stress the structure of the model and the insights obtained from the analysis that has been carried out using the model, including: what issues were addressed and not addressed in the model, and how issues not included in the integrating model could affect overall conclusions. The sensitivity analysis and the interpretation of the sensitivity analysis should be expanded, and conclusions on the importance of uncertainty in various areas of science made more explicit. What areas of science are most significant for policy conclusions and as targets for future research? As one example, the Subcommittee judged that impacts on plants and aquatic organisms are among the most important potential effects of ozone depletion, yet these impacts are included in the model only by considering changes in one crop, soybeans, and one species of aquatic organisms, anchovies. More comprehensive quantitative assessment of potential impacts on plants and aquatic organisms should be identified as a target for further research and analysis as the risk assessment methodology is further refined. As another example, the integrating model does not include mechanisms relating to the recent observations of ozone depletion over Antarctica. As a result, it would be inappropriate to cite the results of the model as indicating that changes exceeding a few percent in stratospheric ozone concentration will not take place until well into the next century.

The integrating model should have extensive additional technical documentation. A listing of the FORTRAN code is inadequate as a basis for communicating the details of the model. Many parties interested in stratospheric ozone risk assessment may find it valuable to have access to the integrating model in order to carry out analyses of the impacts of CFC emissions on ozone and climate change. The Subcommittee recommends that EPA provide adequate technical documentation of the integrating model in the form of appendices to the risk assessment, and that EPA include in its future plans the development of a "user-friendly" version of the integrating model that can be placed in the public domain for use by others.