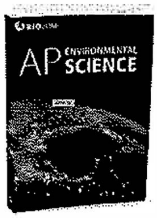
2024-2025 AP Environmental Science
Summer Assignment

The purpose of this summer assignment is to identify examples of things you should be able to do while you are in this course. These are background reference for skills you will use in AP Environmental Science. You will continue to apply skills like this throughout the year. Complete all pages.

Read Laudate Deum, an exhortation from Pope Francis in October 2023. You will have a quiz on it the first day of school.
https://www.vatican.va/content/francesco/en/apost_exhortations/documents/20231004-laudate-deum.pdf

Order AP Environmental Science Biozone book ISBN# 978-1-98-856632-0
There will be a link to order from the company available soon.



Workbook pages are due on the first day of school.
Mrs. Holly Hedrick
hhedrick@bmhs.us (intermittently checked during Summer Break)

Learning Objectives

10. Science Practices for Environmental Science

Developing understanding

Science practices: Science practices describe the things you should be able to do while you are covering the content of this environmental science course. They represent the practices that underlie the study of any science and are categorized into skills. See the table on page vii-ix at the front of this book for a list of skills and practices.

Skills: This supporting unit provides a background reference for the skills you will use throughout this course of study. You will apply these skills as you complete the activities in this book. These skills form the basis of the tasks on the APES exam.

1 Concept explanation ..... activity 172

- ☐ A. To describe environmental concepts and processes you will need to identify relevant features of a concept or process.
- ☐ B. To explain environmental concepts or processes you will need to provide explanatory detail relating to the concept or process, rather than just describing its components.
- ☐ C. To explain environmental concepts or processes in applied contexts you must relate your explanations to real world situations, e.g. explaining how birth and death rates change during demographic transition.

2 Visual representations ..... activity 173

- ☐ A. Describing the features of an environmental concept, process, or model represented visually might involve describing the features of a diagram or a plot.
- ☐ B. Explaining relationships between characteristics of concepts/processes represented visually might involve comparing or predicting patterns or trends or explaining a visual model.
- ☐ C. Explaining how a visual representation relates to broader issues might involve drawing a conclusion based on concepts or processes in the model or representation.

3 Text analysis ..... activity 174

- ☐ A. To identify an author's claim you must be able to identify and state the main point the author is making in the text.
- ☐ B. Describing the author's perspective and assumptions involves being able to recognize the point of view of the author and what assumptions that point of view involves.
- ☐ C. Describing the author's reasoning requires you to describe the evidence supporting the author's claim.
- ☐ D. Evaluating the credibility of a source involves recognizing bias and evaluating scientific accuracy (how true it is).
- ☐ E. Evaluating the validity of conclusions requires that you recognize and describe the limitations of an investigation.

4 Scientific experiments ..... activity 175

- ☐ A. Identifying a testable hypothesis means asking, refining, and evaluating questions about natural phenomena.
- ☐ B. To identify methods, designs, or measures you need to identify variables, and identify and evaluate controls.
- ☐ C. To describe a method, design, or measure you need to describe the variables and the method of data collection.
- ☐ D. To make observations or collect data from laboratory setups you will need to collect first-hand data from observations.

5 Data analysis ..... activity 176

- ☐ A. Describing patterns or trends in data involves visualizing patterns over the time of the data.
- ☐ B. To describe relationships in data you need to describe *how* the dependent variable changes in response to the independent variable.
- ☐ C. To explain patterns and trends in data to draw conclusions you must be able to explain *why* the dependent variable changes in response to the independent variable.
- ☐ D. To interpret data in relation to a hypothesis you must explain *why* the dependent variable responded the way it did to the independent variable.
- ☐ E. To explain what the data illustrates about environmental issues you need to be able to make and then justify a prediction based on data, or justify a given prediction.

6 Mathematical routines ..... activity 177

- ☐ A. To determine an approach for solving a problem you need to be able to explain the best way to calculate a quantity.
- ☐ B. Applying mathematical relationships to solve problems involves calculating values, with working shown.
- ☐ C. Calculating an accurate numerical answer with appropriate units involves awareness of significant figures and units.

7 Environmental solutions ..... activity 178

- ☐ A. To describe environmental problems you need to recognize and then describe a problem.
- ☐ B. To describe potential responses to environmental problems you need to first recognize the causative factors in the problem and their relative contributions to the problem.
- ☐ C. Describing advantages, disadvantages, or unintended consequences of potential solutions to environmental problems recognizes that no solution is without risk or cost. Solutions must be feasible and realistic.
- ☐ D. Using data and evidence to support a potential solution may involve evaluating data to compare the viability of different possible solutions or proposing a solution based on data gathered over a period of time.
- ☐ E. Making a claim that proposes a solution to an environmental problem in an applied context must involve a real world application such as sustainable agriculture or urban mining (extraction of metals from e-waste).
- ☐ F. To justify a proposed solution you must explain its advantages and weigh them against the benefits and drawbacks of alternative solutions.

Key Question: When and how should systems be described or explained using text?

Putting data or a diagram into words adds information that may not be obvious in the data. Explanations can be added to descriptions of data and so better explain the concept being shown. Sometimes data or diagrams can be complex or show multiple concepts. It is important to be able to describe and explain these and how they relate to each other.

Describing a concept may include:

- Describing characteristics and attributes using defining terms, e.g. describing a process as a positive or negative feedback loop.
- Classifying or grouping concepts or parts of concepts, e.g. identifying trophic levels.
- Describing components, e.g. describing the parts involved in carbon cycling.
- Describing how a process occurs, e.g. giving a simple description of an ecological process.
- Describing structure and function, e.g. describing the structure of energy pyramids and the function of each component.
- Describing trends and patterns, e.g. describing patterns in graphs or data tables.

Explaining a concept may include:

- Explaining each of the points in the description table on the left.
- Explaining these points in applied contexts. This might include:
  - Explaining the effect of domestication on biodiversity.
  - Explaining the relationship between photosynthesis and carbon cycling.
  - Explaining competition or cooperation between and within species.
  - Explaining how birth rates change as countries become more developed or industrialized.

- The data below shows the temperature and daylight hours of four cities located in the Americas.

High and (low) temperatures (°C)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New York	4 (-3)	6 (-2)	11 (2)	18 (7)	22 (12)	27 (18)	29 (20)	29 (20)	25 (16)	18 (10)	13 (6)	7 (0)
Miami	23 (17)	24 (18)	25 (19)	26 (21)	28 (23)	30 (25)	31 (26)	31 (26)	30 (25)	28 (24)	26 (21)	24 (19)
Quito	19 (9)	19 (10)	19 (9)	19 (10)	19 (9)	19 (9)	19 (8)	20 (9)	20 (9)	20 (9)	19 (9)	19 (9)
Rio Gallegos	20 (8)	20 (7)	17 (5)	13 (3)	9 (0)	5 (-2)	5 (-2)	8 (-1)	12 (1)	15 (3)	17 (5)	19 (7)

Average monthly daylight hours

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New York	9.5	10.5	12	13	14.5	15	15	14	12.5	11	10	9.5
Miami	10.5	11.5	12	12.5	13.5	13.5	13.5	13	12.5	11.5	11	10.5
Quito	12	12	12	12	12	12	12	12	12	12	12	12
Rio Gallegos	16	14.5	12.5	10.5	9	8	8.5	9.5	11.5	13.5	15.5	16.5

1. The four cities above are Miami (USA), New York (USA), Quito (Ecuador), and Rio Gallegos (southern Argentina).

   (a) Describe two trends in the daylight hours shown in the table above:

   i. _____

   _____

   ii. _____

   _____

   (b) Explain the relationship between daylight hours and the position of the city in the Americas:

   _____

   _____

   _____

   (c) Explain the relationship between a city's temperature and its position in the Americas:

   _____

   _____

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173 Visual Representations

Key Question: How are diagrams and models useful for explaining scientific concepts?

Diagrams and models are important ways of visually representing scientific concepts and ideas. They help explore and explain concepts and can be used to some the complexity of relationships within a system.

Describing visual representations may include:

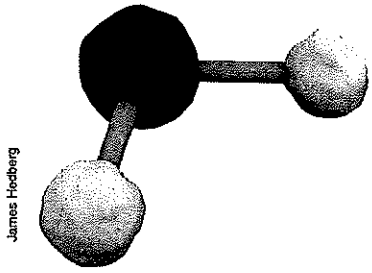
- Describing the characteristics and attributes of the representation, e.g. how are various parts related or connected?
- Describing patterns or trends, e.g. describing trends in graphs or diagrams.

Explaining visual representations may include:

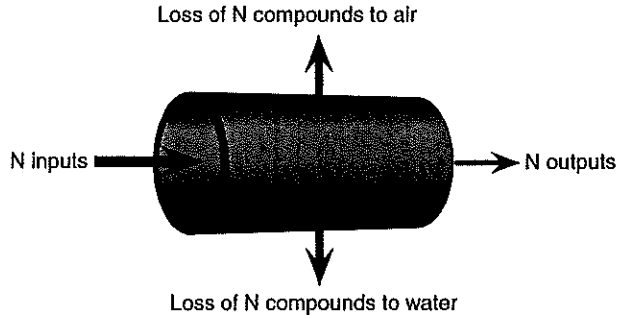
- Comparing patterns or trends, e.g. how does the monthly temperature in city A compare to the monthly temperature in city B?
- Explaining the concept being represented visually, e.g. explaining what the flow diagram is showing.
- Predicting patterns based on the representation/model.
- Drawing conclusions based on the information being represented visually.

▶ Scientific concepts and data can be represented or modeled in many different ways. The way the data is represented depends on the concept being expressed Some examples of visual representations are shown here:

A: Physical model of a water molecule

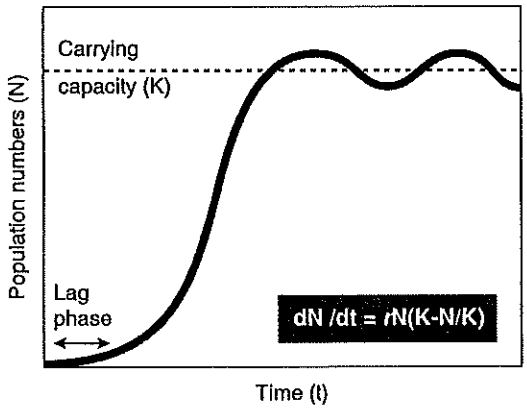


B: Nitrogen inputs and outputs

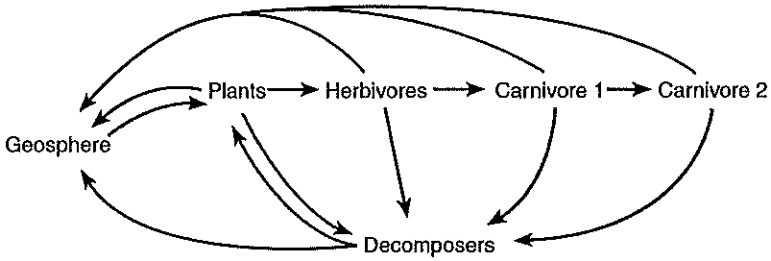


Nitrogen balance = Nitrogen input – Nitrogen output + N lost

C: Mathematical model of population growth



D: Diagram of nutrient cycling in an ecosystem



1. For each of the models A - D describe what each is showing:

   A: _____

   B: _____

   C: _____

   D: _____

2. (a) Use the diagram D above to explain nutrient movements in an ecosystem: _____

   _____

   _____

   (b) Use the diagram C above to predict the effect of reducing the carrying capacity by half: _____

   _____

   _____

Key Question: Why is carefully analyzing text and written documents so important?

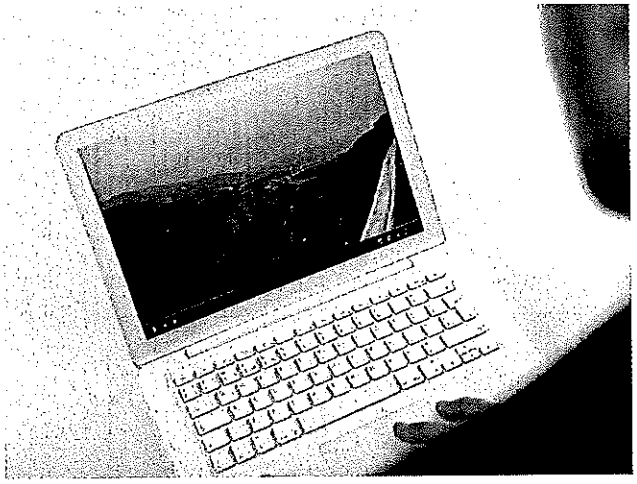
The amount of written information available on any particular topic has increased exponentially since the internet became readily available. Choose any environmental topic and there will be hundreds if not thousands of websites on it. Some will be factual, others will be opinionated, some will be just inaccurate, and a few will be intentionally misleading. Data and information should be checked to make sure it comes from a reputable source. It is also important to make sure the information has not been used out of context or been "cherry picked" for data to put forth biased ideas.

Text analysis may include:

- Describing the article:
  - Stating the main points in article.
  - Describing the author's perspectives and assumptions.
  - Identifying any claims made by the author and any evidence presented to justify them.
- Evaluating the article:
  - Identifying and describing any bias in the article. Describe how this may have affect the articles accuracy.
  - Describing the limitations of an investigative article.
  - Describing the article's conclusions.

What can be trusted?

- Environmental science covers many contentious and emotive topics. Many new ideas about the environment clash with traditional views or threaten livelihoods and economies. As a result people may have certain views they feel invested in. This leads to people putting forth information to support their view, lobbying to a certain extent.
- When reading environmental information, especially on the internet, it is important that you take note of where the information comes from and whether it makes sense in a wider context. This will help you identify biased or flawed information.
- Note the site from which you obtained information. Is it reputable or just someone's blog with their own unverifiable ideas? Be cautious with video clips (e.g. YouTube). Again, these often present an unsubstantiated personal view. Check the comments as they may identify errors (if any) in the video.



Evaluating environmental information

- In order to form an opinion about the information presented, you must critically evaluate the information. Points to consider include:
- Validity of the information.
  - The currency of the information. Is it up to date?
  - Is the information peer reviewed? Has it been accepted by the scientific community?
- Does the information present an unbiased view?
  - Is information presented in a fair, unbiased way? Is it based on fact and not emotion?
  - Is the information presented clouded by the attitudes, beliefs, or values of the person, group, or organization supplying the information?
- Journals are peer-reviewed. That is, the information is checked by experts in the topic area. This greatly improves the reliability of the information. However, journals are often very technical and require a high level of in-area expertise to understand.
- Newspaper articles are a good starting point as a source of generally reliable information, but beware of the newspaper's particular leaning. Tabloids often sensationalize stories, while some newspapers may have left or right political leanings, which can skew the focus of a story.
- Online sites that are specific for a topic need to be carefully scrutinised for validity. Stay away from conspiracy sites as these often sensationalize stories and misreport the sceince. Government sites often have the most current and reliable data based on information from skilled advisers.

- Periodicals or technical magazines, e.g. National Geographic, Scientific American, or Popular Mechanics, are useful sources of reliable information. As they are written for the general public they make understanding the technical information much easier.

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▶ Read the article below and answer the questions:

Glacial stream insect may tolerate warmer waters

Scott Hotaling *et al*, Mountain stoneflies may tolerate warming streams: evidence from organismal physiology and gene expression. Global Change Biology, 2020; DOI: 10.1111/gcb.15294. Text below based on an article in Science Daily.

Stoneflies may be able to tolerate warmer water temperatures and may even be stressed in their cold water environment. This goes against most current theory which states that rising temperatures will be disastrous for glacial stream insects and ecology. However lead author Scott Hotaling says that still may be so for mountain stoneflies.

"These species are still in peril," says Hotaling. "They live in these extreme environments for a reason, but we don't fully understand why. Threats from warming and loss of glaciers are likely more complicated, and potentially, it is not about physical factors. It might be about ecological factors."

Hotaling and his colleagues tested the thermal tolerance of several species of mountain stoneflies found in the Rocky Mountains, at least one of which was listed under the Endangered Species Act due to rapid loss of its glacial habitat. The researchers collected larval specimens of the stoneflies from streams in Glacier and Grand Teton National Parks. Some of the larvae were then subjected to increasingly warmer water temperatures over short time periods, imitating what might happen to a stream on a hot summer day.

All of the species could tolerate waters of at least 20°C, well above the maximum 10°C of their natural habitat.

Hotaling and his team found that the stoneflies that experienced warmer temperatures expressed "heat shock proteins" within the cells. These proteins are named because they were first discovered in relation to exposure to high temperatures. It has since been found that heat shock proteins are also related to other stressful events, including exposure to cold.

The study found that the heat shock proteins were also present in the stoneflies kept in water at 3°C, similar to the temperature of their glacial habitat. This indicated the stoneflies might be stressed in their natural home.

The study raises many questions, such as why the insects aren't found naturally in warmer waters. Co-author Alisha Shah says: "It is possible that these mountain stoneflies are just bad competitors, and they are pushed up to these higher elevations by stronger competitors that prefer somewhat warmer temperatures."

The researchers are now investigating how stoneflies respond to living in warmer water for longer periods (as might happen with global warming). So far, the stonefly nymphs appear to develop faster. Shah said it was hard to tell yet if that was good or bad since faster development might mean the stoneflies produce more deformities or fewer eggs. Hotaling and Shah are investigating these variables in a race to better understand the cold communities that live downstream of glaciers before they disappear.

"We're stuck between having so little knowledge about the ecology and physiology of what lives on or downstream of glaciers and having so little time," Hotaling says. "These are some of the most rapidly changing places on the planet, so we have little time left have to understand them."

1. State the main purpose of the article: _____

2. What does the author claim about the stonefly's ability to withstand climate change? _____

3. What evidence is there for these claims? _____

4. Are there any limitations in the investigation? _____

5. What are the study's conclusions? _____

6. Are there any assumptions made? If so, what are they? _____

Key Question: What methods should be used to carry out, write, and analyze scientific investigations?

Articles in scientific journals are written in a standardized way. They usually open with an abstract, which summarizes the reasons for carrying out the investigation, the results and conclusions. They include methods, so others can reproduce or modify the method in their own experiments, and the results. They finish with the conclusions, often written as part of a discussion. You should be able to understand this format and extract important data from it.

Describing aspects of scientific investigations may include:

- Identifying the purpose or aim of the investigation, or the hypothesis being tested.
- Identifying and describing the method, including the dependent and independent variables.
- Identifying the control (if present) and justifying any factors that need to controlled.
- Being able to draw data from the method and results, including photographs and diagrams (e.g. graphs).
- Identifying and describing how a method could be modified or refined to obtain more accurate data.

Carrying out a scientific investigation may include:

- Identifying the aim and writing a hypothesis.
- Deciding which variable will be changed (the independent variable) and which will be measured (the dependent variable) and how this will done.
- Writing the method of data collection so that it can be followed and repeated by someone else.
- Recording data in a systematic way.
- Drawing conclusions from the data.
- Writing a concluding discussion identifying what the results mean and any limitations in the investigation.

Start with an observation, ask a question, then write a hypothesis

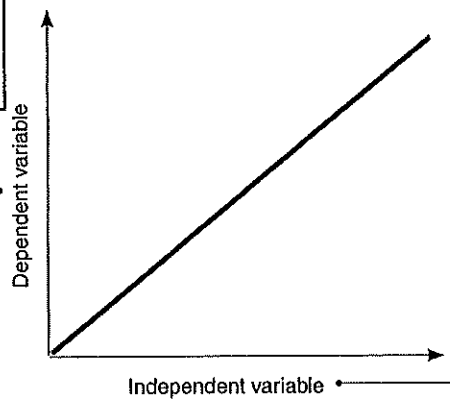
- Investigations normally start from observations, either from a previous investigation or from observing natural phenomena. An observation could be: there are more exhaust fumes during rush hour, summers appear to be getting warmer, or its harder to catch fish from the jetty now than a decade ago.
- These observations may or may not be true, but they allow us to ask questions: Is air pollution greater during rush hour? Are the summers getting hotter? Are the local fish populations getting smaller? We can turn the questions into statements than can be tested to be true of not, that is, the statement (hypothesis) can be accepted or rejected.
- For example: There are higher levels or particulate matter in the air during rush hour than during other times of the day. This statement can be tested by measuring amounts of particulate matter at different times of the day. If particulate matter is higher during rush hour then the statement can be accepted. If not, it can be rejected.

Identifying variables

- A **variable** is any characteristic or property able to take any one of a range of values. Investigations often look at the effect of changing one variable on another. It is important to identify all variables in an investigation: independent, dependent, and controlled, although there may be nuisance factors of which you are unaware. In a fair test, only one variable is changed by the investigator.

Dependent variable

- Measured during the investigation.
- Recorded on the y axis of the graph.



Controlled variables

- Factors that are kept the same or controlled.
- List these in the method, as appropriate to your own investigation.

Independent variable

- Set by the experimenter.
- Recorded on the graph's x axis.
- Should include at least four different values.

1. What are the independent and dependent variables for the example in red text above:

   (a) Dependent: _____

   (b) Independent: _____

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Experimental controls

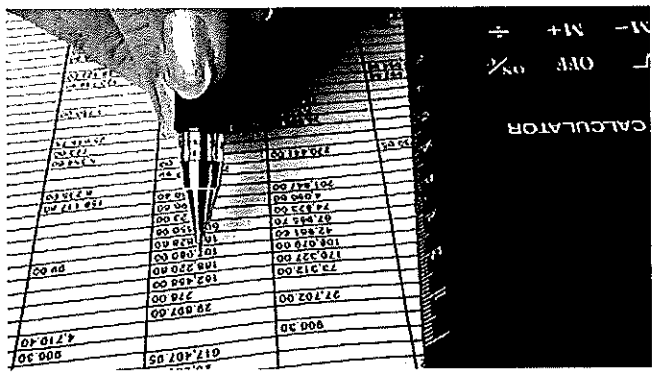
- A **control** refers to a standard or reference treatment or group in an experiment.
- It is the same as the experimental (test) group, except that it lacks the one variable being manipulated by the experimenter.
- Controls are used to demonstrate that the response in the test group is due a specific variable (e.g. temperature).
- The control undergoes the same preparation, experimental conditions, observations, measurements, and analysis as the test group. This helps to ensure that responses observed in the treatment groups can be reliably interpreted.
- Data gathering investigations, such as the one for particulate matter already mentioned, sometimes have the control built into the investigation. By measuring particulate levels at set time intervals throughout the day the experimental group (rush hour) and the control (non-rush hours) can be compared.

Gathering data

- Investigations should be carried out multiple times in order to make sure the data collected is consistent.
- Multiple trials and measurements for the same variable allow statistics (e.g. the mean) to be calculated.
- The more trials and data gathered, the more confident you can be of the final results, providing there is no systematic bias in your methodology.

How do I analyze my data?

- Check your data to see that it makes sense. Do the results seem logical? Are there any outliers? If so, you must decide whether to include them in your analysis.
- Raw data may need to be transformed to see trends and patterns. These transformations may be quite simple (e.g. percentages, rates, ratios). Other transformations are used to normalize the data so that it can undergo further analysis (e.g. log transformations when working with large numbers).
- Descriptive statistics (e.g. mean and standard deviation) provide a way to summarize your data, and provide results that can easily be presented and compared across groups. Summary statistics are also useful in identifying trends and patterns in the data.
- Sometimes an appropriate statistical analysis is required to test the significance of results. However, with simple experiments, if the design is sound, the results are often clearly shown in a plot of the data.

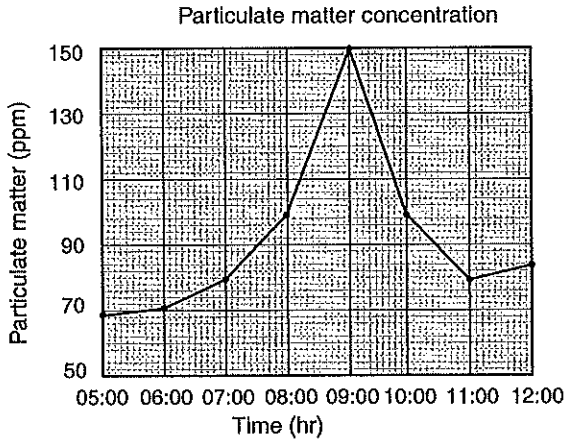


Presenting your data

Tables and graphs provide a way to organize and visualize data in a way that helps to identify trends. Each has a different purpose. Tables provide an accurate record of numerical values and allow you to organize your data so that relationships and trends are apparent. Columns can be inserted for calculations such as rates. Graphs provide a visual representation of trends in the data in a minimum of space and are an excellent choice for displaying results in a poster or report. Histograms, line graphs, and scatter graphs are common ways to display data graphically. The graph and table below display the same data.

Level of particulate matter from 05:00 to 12:00 hours

Time (hr)	ppm particulate matter
05:00	70
06:00	71
07:00	80
08:00	100
09:00	150
10:00	100
11:00	80
12:00	85



Conclusions and discussion

Your conclusions summarize how your results support (or don't support) the hypothesis. Your may include a discussion of what the results mean and what caused them. Usually this discussion is within the context of what is already known and published. Any limitations of the investigation should be included. In scientific journals the discussion is often one of the longest sections. It may discuss the significance of the results in a wider context and so is probably the most important part of the report.

2. What do the results above show? What might cause them and why are they significant? _____

_____

_____

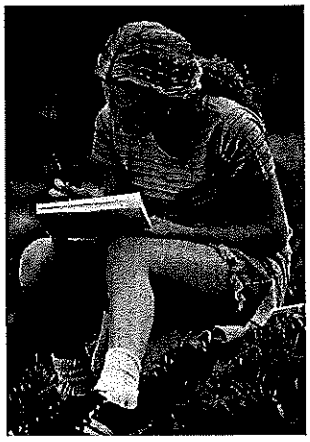
_____

Key Question: How can we analyze data?

Once data has been collected its is important to be able to analyze or interpret it in order to make sense of it. Graphs are an excellent way to summarize trends in data or relationships between different variables. It is important to be able to be construct and interpret different kinds of graph. Common graphs include scatter plots and line graphs (for continuous data), and bar charts (for categorical data).

Interpreting data may include:

- Describing patterns or trends (e.g. does a variable rise or fall over time).
- Describing how the dependent variable changes in response to changes in the independent variable.
- Explaining why the dependent variable changes in response to changes in the independent variable.
- Making predictions based on trends in the data and justifying the prediction.
- Justifying the predictions of others based on the data presented.



Types of data

Quantitative (interval or ratio)
Characteristics for which measurements or counts can be made, e.g. height, weight, number.
Summary measures: mean, median, standard deviation

Qualitative (nominal)
Non-numerical and descriptive, e.g. sex, color, viability (dead/alive), presence or absence of a specific feature.
Summary measures: frequencies and proportions

e.g. Sex of children in a family (male, female)

Ranked (ordinal)
Data are ranked in order, although the intervals between the orders may not be equal, e.g. abundance (abundant, common, rare).
Summary measures: frequencies and proportions

e.g. Birth order in a family (1, 2, 3)

Discontinuous (discrete)

e.g. Number of children in a family (3, 0, 4)

Continuous

e.g. Height of children in a family (1.5 m, 0.8 m)

Discontinuous or discrete data:
The unit of measurement cannot be split up (e.g. you cannot have half a child).

Continuous data:
The unit of measurement can be a part number (e.g. 5.25 kg).

Presenting data in tables

- Tables provide a way to systematically record and condense a large amount of information. They provide an accurate record of numerical data and allow you to organize your data in a way that allows you to identify relationships and trends. This can help to decide the best way to graph the data if graphing is required.
- Table titles and row and column headings must be clear and accurate so the reader knows exactly what the table is about. Calculations such as rates and summary statistics (such as mean or standard deviation) may be included on a table.
- Summary statistics make it easier to identify trends and compare different treatments. Rates are useful in making multiple data sets comparable, e.g. if recordings were made over different time periods.

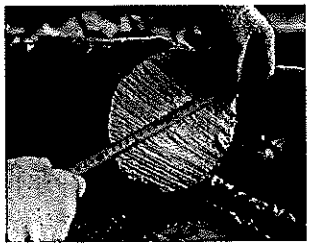
Table 1: Population, land area, and calculated population density in four US states.

State	Population	Land area (km^2)	Population density (people/km)
Alabama	4,871,547	135,754	35.9
Florida	20,636,975	170,307	121.2
Montana	1,032,949	380,847	2.7
Texas	27,469,114	695,662	39.5

1. For each of the photographic examples A-C below use the flow chart top to classify the data.

A: Flower color

B: Eggs per nest



C: Tree trunk diameter

A: _____

B: _____

C: _____

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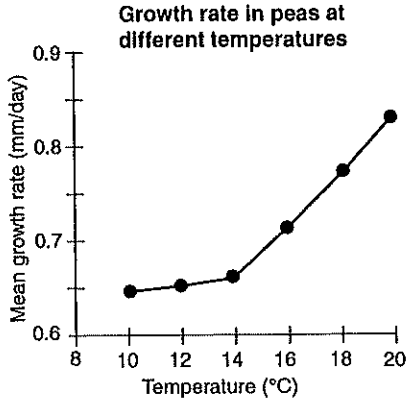
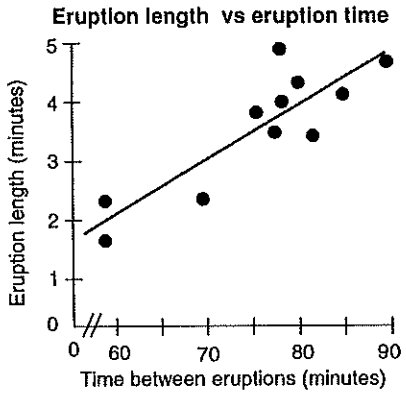
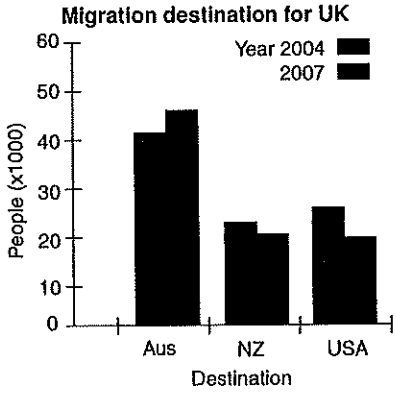
Presenting data in graphs

- Graphs are a good way to show trends, patterns, and relationships visually without taking up too much space. Complex data sets tend to be presented as a graph rather than as a table, although the raw data can sometimes be tabulated as an appendix.
- Presenting graphs properly requires attention to a few basic details, including correct orientation and labeling of the axes, accurate plotting of points, and a descriptive, accurate title.
- Before representing data graphically, it is important to identify the kind of data you have. Common graphs include scatter plots and line graphs (for continuous data), and bar charts (for categorical data). For continuous data with calculated means, points can be connected. On scatter plots, a line of best fit is often drawn.







Guidelines for line graphs

- Line graphs are used when one variable (the independent variable) affects another, the dependent variable.
- The data must be continuous for both variables. The independent variable is the experimental treatment. The dependent variable is the response.
- The relationship between two variables can be represented as a continuum and the plotted data points are connected directly (point to point).

Guidelines for scatter graphs

- A scatter graph is a common way to display continuous data where there is a relationship between two interdependent variables.
- There is no independent (manipulated) variable, but the variables are often correlated, i.e. they vary together in a predictable way.
- The points on the graph are not connected, but a line of best fit is often drawn through the points to show the relationship between the variables

Guidelines for bar/column graphs

- Bar and column graphs are appropriate for data that are non-numerical and discrete (categorical) for one variable. There are no dependent or independent variables.
- Data is discontinuous so bars do not touch (continuous data can be shown on a histogram where bars do touch).
- Multiple sets of data can be displayed side by side for comparison (e.g. males and females in the same age group).

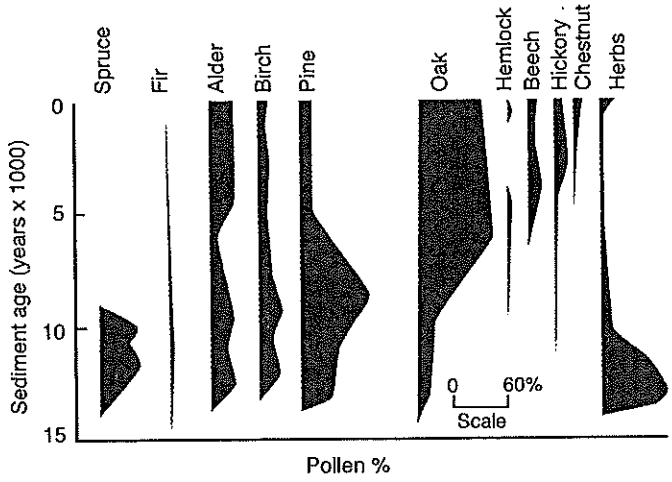
2. Explain the choice of graph types for the three data sets above: _____

_____

_____

_____

3. The data below shows the percentage of pollen in sediments from a region in northeastern United States, laid down over 15,000 years. By graphing the percentages of pollen types beside each other and matching the pollen type to known trees and landscapes we can develop a picture of what the land looked like at any particular time in the last 15,000 years.



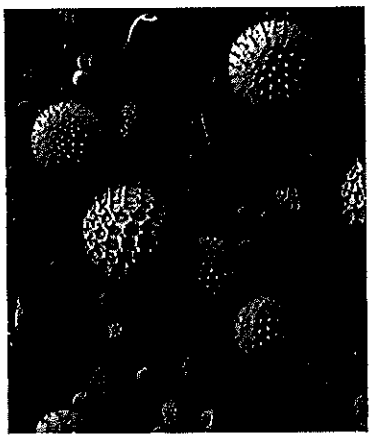
Farmland, woodlots

Hardwood forest

Pine-hardwood

Open spruce forest

Tundra



Dartmouth Electron Microscope Facility (Public Domain)

(a) What was the most common tree type(s) 10,000 years ago? _____

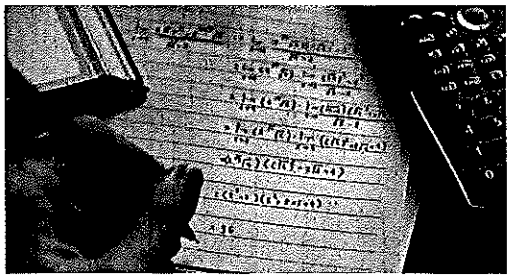
(b) What was the predominant forest type 5000 years ago? _____

Key Question: What mathematical process can be used to help data analysis?

Mathematics is used to analyze, interpret, and compare data. It is important that you are familiar with mathematical notation (the language of mathematics) and can confidently apply some basic mathematical principles and calculations to your data. Data collected in the field or laboratory is called raw data. It often needs to be transformed in order for trends or patterns to be reveled. Ratios and percentages are widely used. Large numbers may be transformed using logarithms. Log transformations reduce skew, make large numbers easier to work with, and can make data easier to interpret.

Using mathematical routines may include:

- Determining the best method to solve a mathematical problem, e.g. explaining the best way to compare coal use between countries.
- Applying appropriate mathematical routines or relationships to solve a problem, with working shown e.g. calculating population growth over time.
- Calculating a numeric answer to a problem, using the appropriate units, e.g. calculating the energy required to power a town for 10 years.



Conversion factors: metric to common units

LENGTH	Multiply by
Centimeters to inches:	0.393
Meters to feet:	3.280
Kilometers to miles:	0.621
VOLUME	
Milliliters to fluid ounces:	0.034
Liters to gallons:	0.264
AREA	
Square meters to square feet:	10.76
Hectares to acres:	2.471
Square kilometers to square miles	0.386
TEMPERATURE	
°C to °F:	Freezing point of water: 0 °C = 32 °F Boiling point of water : 100 °C = 212 °F
Formula °C to °F:	°F = °C x 1.8 + 32
Energy	
BTU to joules	1055.0558

Percentages

Percentages are expressed as a fraction of 100 (e.g. 20/100 = 20%).

Percentages provide a clear expression of what proportion of data fall into any particular category, e.g. for pie graphs.

Allows meaningful comparison between different samples.

Useful to monitor change (e.g. % increase from one year to the next (example below)).

Example: A study of a bear population counts 75 bears living within a 300 km^2 forest. 25 of them were male:

1. Calculate the % of male bears in the population.
   25/75 x 100 = 33%
2. It is estimated that the bear population may be 20% larger than the raw count suggests. Calculate the new population:
   75 + (75 x 0.20) = 90 bears.
3. It is estimated the population has an annual growth rate of 3%. Calculate the bear population in five years time:
   $Pop_{future\ bears} = Pop_{present\ bears} \times (1 + 0.03)^5 = 75 \times (1.03)^5$
   = 87 bears in 5 years

Decimal and standard form

Decimal form (also called ordinary form) is the longhand way of writing a number (e.g. 15,000,000). Very large or very small numbers can take up too much space if written in decimal form and are often expressed in a condensed **standard form.** For example, 15,000,000 is written as 1.5×10^7 in standard form.

In standard form a number is always written as $A \times 10^n$, where A is a number between 1 and 10, and n (the exponent) indicates how many places to move the decimal point. n can be positive or negative.

For the example above, A = 1.5 and n = 7 because the decimal point moved seven places (see below).

$$1\overset{1}{5}0\overset{2}{0}0\overset{3}{0}0\overset{4}{0}0\overset{5}{0}0\overset{6}{0}0\overset{7}{0} = 1.5 \times 10^7$$

Small numbers can also be written in standard form. The exponent (n) will be negative. For example, 0.00101 is written as 1.01×10^{-3}.

$$0.\overset{1}{0}0\overset{2}{1}0\ 1 = 1.01 \times 10^{-3}$$

Adding numbers in standard form

Numbers in standard form can be added together so long as they are both raised to the same power of ten.
E.g: $1 \times 10^4 + 2 \times 10^3 = 1 \times 10^4 + 0.2 \times 10^4 = 1.2 \times 10^4$

Rates

Rates are expressed as a measure per unit of time and show how a variable changes over time. Rates are used to provide meaningful comparisons of data that may have been recorded over different time periods.

Often rates are expressed as a mean rate over the duration of the measurement period, but it is also useful to calculate the rate at various times to understand how rate changes over time. The table below shows the distance a fault line moves over a decade. A worked example for the rate at 4 years is shown.

Time (year)	Distance traveled (mm)	Rate of movement (speed) (mm/year)	Mean rate of movement (mm/year)
0	0	0	0
2	40	20	20
4	100	30*	25
6	120	10	20
8	170	25	21
10	200	15	20

*mm moved between 2 - 4 years: 100 mm − 40 mm = 60 mm

Rate of movement (speed) between 2 - 4 years
60 mm ÷ 2 years = 30mm/year

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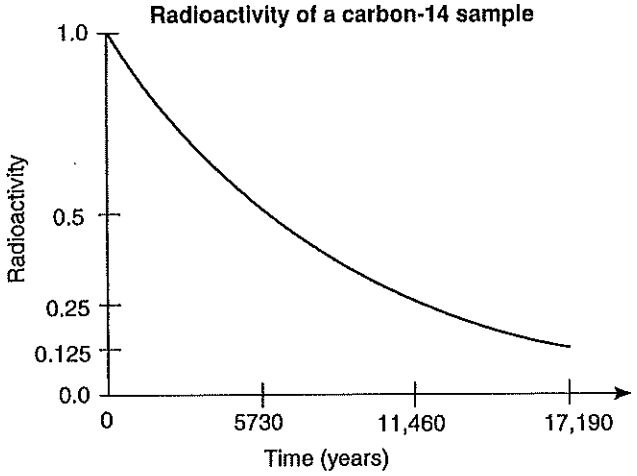
Dealing with large numbers

- Environmental science often deals with very large numbers or scales. Numerical data indicating scale can often increase or decrease exponentially. Large scale changes in numerical data can be made more manageable by using log transformations.

Exponential function

- Exponential growth or decay occurs at an increasingly rapid rate in proportion to the increasing or decreasing total number or size.
- In an exponential function, the base number is fixed (constant) and the exponent is variable.
- The equation for an exponential function is $y = c^x$.
- An example of exponential decay is radioactive decay. Any radioactive element has a half-life, the amount of time required for its radioactivity to fall to half its original value.



Example above: Carbon-14 (^{14}C) has a half life of 5730 years. If a sample with a mass of 10 g was left for 5730 years half the sample will have decayed, leaving 5 g of radioactive material. After another 5730 years, 2.5 g of radioactive carbon will be left.

Log transformations

- A log transformation can make very large numbers easier to work with.
- The log of a number is the exponent to which a fixed value (the base) is raised to get that number. So $\log_{10}(1000) = 3$ because $10^3 = 1000$.
- Both $\log_{10}$ and $\log_e$ (natural logs or *ln*) are commonly used.
- Log transformations are useful for data where there is an exponential increase or decrease in numbers. In this case, the transformation will produce a straight line plot.
- To find the $\log_{10}$ of a number, e.g. 32, using a calculator, key in log 32 = . The answer should be 1.51.
- Instead of transforming the data it can be plotted on a log grid, where grid lines are spaced out logarithmically either on both axes (log-log grid) or on one axis (semi-log grid).
- An example of the difference between raw numbers and log transformations is described below. The data shows the growth of a newly established squirrel population in a park.

Squirrel population		
Year (since establishment)	Population	Log_{10} of population
0	10	
1	12	
3	17	
5	25	
7	37	
9	53	
12	93	

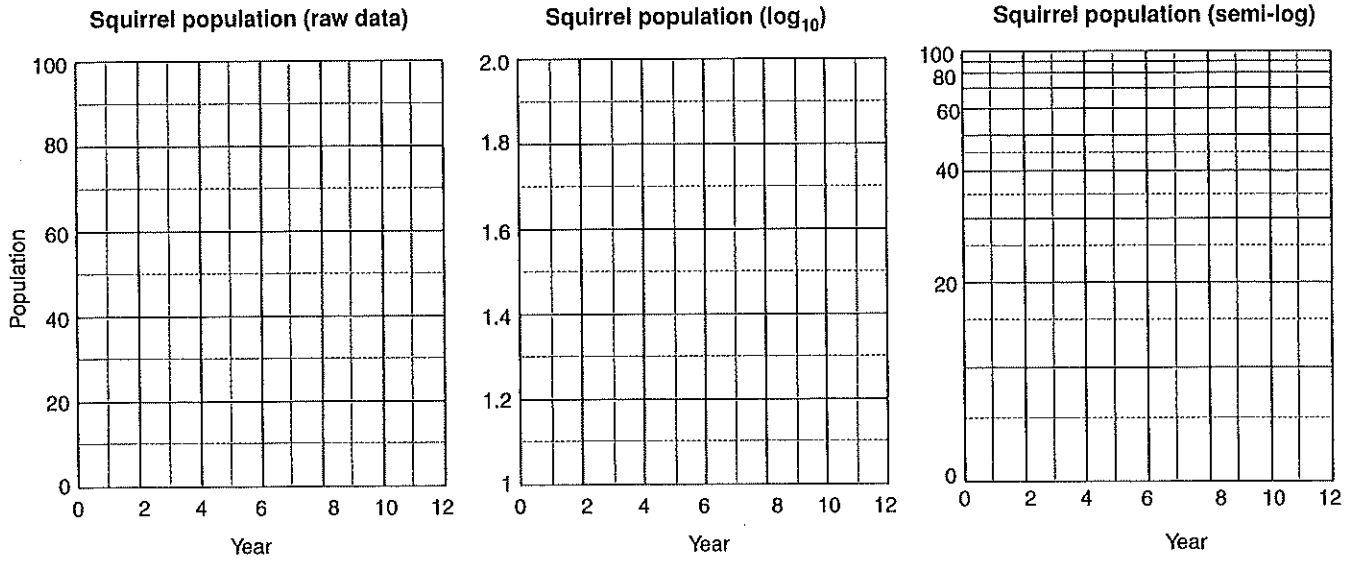
1. (a) Complete the table above right by calculating the $\log_{10}$ of the population:

   (b) Draw a line graph of the squirrel population using the raw data:

   (c) Draw a line graph of the squirrel population using the log transformed data:

   (d) Draw a line graph of the squirrel population on the semilog graph using the raw data:

   (e) Describe the difference in these graphs: _____

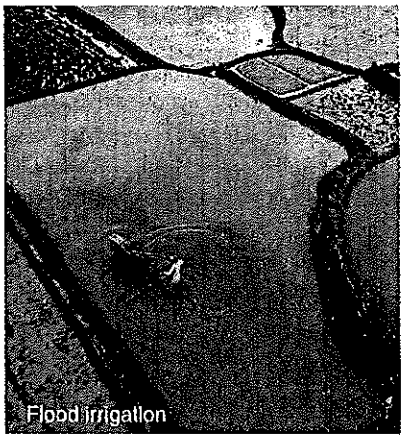


Key Question: What steps might be taken to solve an environmental problem?

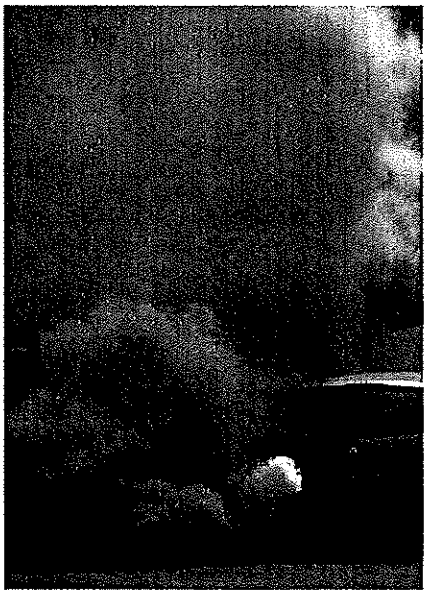
An important part of environmental science is analyzing problems and proposing potential solutions. To do this you will need all the skills and knowledge gained in this program of study. Solving problems involves gathering and analyzing data, identifying a solution and its advantages and disadvantages, and justifying the potential outcome.

Solving environmental problems may include:

- Describing the problem:
  - Describing environmental problem, e.g. unsustainable population growth.
  - Describing potential responses to environmental problems, e.g. reducing human impacts on the environment.
  - Describing the advantages and disadvantages of a potential solution to an environmental problem, e.g. determining how realistic a proposed solution is.
- Using data:
  - Using data to identify and justify which solutions are viable.
  - Proposing solutions to environmental problems based on gathered data.
- Justifying a claim:
  - Proposing a solution to an environmental problem in an applied context (e.g. agriculture) and justifying the claim (e.g. explaining the advantages of a proposed irrigation practice).


Flood irrigation

- Cars and trucks produce about 20% of the CO_2 emissions of the United States. This is an important environmental problem but people have many different opinions on how to solve it, from building more electric vehicles, to using more public transport.
- Some students were discussing how to reduce the air pollution caused by cars. Each made a claim (below):



Student 1: "Cars using gasoline have higher fuel consumption than cars using diesel. One liter of diesel takes you further than one liter of gasoline. Therefore all cars should run on diesel so that we use less fossil fuel, which produces less carbon dioxide and is better for the environment."

Student 2: "Diesels produce more particulate matter from the exhaust and more NOx gases than other fuels. This creates smog and more air pollution. Therefore diesels should be banned."

Student 3 : "We should use electric cars because they don't use fossil fuels or produce carbon dioxide."

Student 4: "If everyone used electric cars there would no off-peak time for electricity generation. Power stations would have to use more fuel, which can produce CO_2. And we don't know the environmental effect of used batteries."

Student 5: "People should be encouraged to use public transport. That would reduce the number of cars on the road."

Student 6: "People aren't going to want to give up their cars for something that's less convenient or more expensive."

Some of the opinions above present a solution, others present an argument for or against the solution. A solution to an environmental problem needs to be able to justify its use.

1. Choose two of the claims and explain what needs to be done to justify the claim:

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The Holy See

APOSTOLIC EXHORTATION

LAUDATE DEUM

OF THE HOLY FATHER
FRANCIS

TO ALL PEOPLE OF GOOD WILL
ON THE CLIMATE CRISIS

1. "Praise God for all his creatures". This was the message that Saint Francis of Assisi proclaimed by his life, his canticles and all his actions. In this way, he accepted the invitation of the biblical Psalms and reflected the sensitivity of Jesus before the creatures of his Father: "Consider the lilies of the field, how they grow; they neither toil nor spin, yet I tell you, even Solomon in all his glory was not clothed like one of these" (*Mt* 6:28-29). "Are not five sparrows sold for two pennies? Yet not one of them is forgotten in God's sight" (*Lk* 12:6). How can we not admire this tenderness of Jesus for all the beings that accompany us along the way!

2. Eight years have passed since I published the Encyclical Letter *Laudato Si'*, when I wanted to share with all of you, my brothers and sisters of our suffering planet, my heartfelt concerns about the care of our common home. Yet, with the passage of time, I have realized that our responses have not been adequate, while the world in which we live is collapsing and may be nearing the breaking point. In addition to this possibility, it is indubitable that the impact of climate change will increasingly prejudice the lives and families of many persons. We will feel its effects in the areas of healthcare, sources of employment, access to resources, housing, forced migrations, etc.

3. This is a global social issue and one intimately related to the dignity of human life. The Bishops of the United States have expressed very well this social meaning of our concern about climate change, which goes beyond a merely ecological approach, because "our care for one another and our care for the earth are intimately bound together. Climate change is one of the principal

challenges facing society and the global community. The effects of climate change are borne by the most vulnerable people, whether at home or around the world". [1] In a few words, the Bishops assembled for the Synod for Amazonia said the same thing: "Attacks on nature have consequences for people's lives". [2] And to express bluntly that this is no longer a secondary or ideological question, but a drama that harms us all, the African bishops stated that climate change makes manifest "a tragic and striking example of structural sin". [3]

4. The reflection and information that we can gather from these past eight years allow us to clarify and complete what we were able to state some time ago. For this reason, and because the situation is now even more pressing, I have wished to share these pages with you.

1. The Global Climate Crisis

5. Despite all attempts to deny, conceal, gloss over or relativize the issue, the signs of climate change are here and increasingly evident. No one can ignore the fact that in recent years we have witnessed extreme weather phenomena, frequent periods of unusual heat, drought and other cries of protest on the part of the earth that are only a few palpable expressions of a silent disease that affects everyone. Admittedly, not every concrete catastrophe ought to be attributed to global climate change. Nonetheless, it is verifiable that specific climate changes provoked by humanity are notably heightening the probability of extreme phenomena that are increasingly frequent and intense. For this reason, we know that every time the global temperature increases by 0.5° C, the intensity and frequency of great rains and floods increase in some areas and severe droughts in others, extreme heat waves in some places and heavy snowfall in others. [4] If up to now we could have heat waves several times a year, what will happen if the global temperature increases by 1.5° C, which we are approaching? Those heat waves will be much more frequent and with greater intensity. If it should rise above 2 degrees, the icecaps of Greenland and a large part of Antarctica [5] will melt completely, with immensely grave consequences for everyone.

Resistance and confusion

6. In recent years, some have chosen to deride these facts. They bring up allegedly solid scientific data, like the fact that the planet has always had, and will have, periods of cooling and warming. They forget to mention another relevant datum: that what we are presently experiencing is an unusual acceleration of warming, at such a speed that it will take only one generation – not centuries or millennia – in order to verify it. The rise in the sea level and the melting of glaciers can be easily perceived by an individual in his or her lifetime, and probably in a few years many populations will have to move their homes because of these facts.

7. In order to ridicule those who speak of global warming, it is pointed out that intermittent periods of extreme cold regularly occur. One fails to mention that this and other extraordinary symptoms are nothing but diverse alternative expressions of the same cause: the global imbalance that is

provoking the warming of the planet. Droughts and floods, the dried-up lakes, communities swept away by seaquakes and flooding ultimately have the same origin. At the same time, if we speak of a global phenomenon, we cannot confuse this with sporadic events explained in good part by local factors.

8. Lack of information leads to confusion between large-scale climate projections that involve long periods of time – we are talking about decades at least – with weather forecasts that at most can cover a few weeks. When we speak of climate change, we are referring to a global reality – and constant local variations – that persists for several decades.

9. In an attempt to simplify reality, there are those who would place responsibility on the poor, since they have many children, and even attempt to resolve the problem by mutilating women in less developed countries. As usual, it would seem that everything is the fault of the poor. Yet the reality is that a low, richer percentage of the planet contaminates more than the poorest 50% of the total world population, and that per capita emissions of the richer countries are much greater than those of the poorer ones. [6] How can we forget that Africa, home to more than half of the world's poorest people, is responsible for a minimal portion of historic emissions?

10. It is often heard also that efforts to mitigate climate change by reducing the use of fossil fuels and developing cleaner energy sources will lead to a reduction in the number of jobs. What is happening is that millions of people are losing their jobs due to different effects of climate change: rising sea levels, droughts and other phenomena affecting the planet have left many people adrift. Conversely, the transition to renewable forms of energy, properly managed, as well as efforts to adapt to the damage caused by climate change, are capable of generating countless jobs in different sectors. This demands that politicians and business leaders should even now be concerning themselves with it.

Human causes

11. It is no longer possible to doubt the human – "anthropic" – origin of climate change. Let us see why. The concentration of greenhouse gases in the atmosphere, which causes global warming, was stable until the nineteenth century, below 300 parts per million in volume. But in the middle of that century, in conjunction with industrial development, emissions began to increase. In the past fifty years, this increase has accelerated significantly, as the Mauna Loa observatory, which has taken daily measurements of carbon dioxide since 1958, has confirmed. While I was writing *Laudato Si'*, they hit a historic high – 400 parts per million – until arriving at 423 parts per million in June 2023. [7] More than 42% of total net emissions since the year 1850 were produced after 1990. [8]

12. At the same time, we have confirmed that in the last fifty years the temperature has risen at an unprecedented speed, greater than any time over the past two thousand years. In this period, the

trend was a warming of 0.15° C per decade, double that of the last 150 years. From 1850 on, the global temperature has risen by 1.1° C, with even greater impact on the polar regions. At this rate, it is possible that in just ten years we will reach the recommended maximum global ceiling of 1.5° C. [9] This increase has not occurred on the earth's surface alone but also several kilometres higher in the atmosphere, on the surface of the oceans and even in their depths for hundreds of metres. Thus the acidification of the seas increased and their oxygen levels were reduced. The glaciers are receding, the snow cover is diminishing and the sea level is constantly rising. [10]

13. It is not possible to conceal the correlation of these global climate phenomena and the accelerated increase in greenhouse gas emissions, particularly since the mid-twentieth century. The overwhelming majority of scientists specializing in the climate support this correlation, and only a very small percentage of them seek to deny the evidence. Regrettably, the climate crisis is not exactly a matter that interests the great economic powers, whose concern is with the greatest profit possible at minimal cost and in the shortest amount of time.

14. I feel obliged to make these clarifications, which may appear obvious, because of certain dismissive and scarcely reasonable opinions that I encounter, even within the Catholic Church. Yet we can no longer doubt that the reason for the unusual rapidity of these dangerous changes is a fact that cannot be concealed: the enormous novelties that have to do with unchecked human intervention on nature in the past two centuries. Events of natural origin that usually cause warming, such as volcanic eruptions and others, are insufficient to explain the proportion and speed of the changes of recent decades. [11] The change in average surface temperatures cannot be explained except as the result of the increase of greenhouse gases.

Damages and risks

15. Some effects of the climate crisis are already irreversible, at least for several hundred years, such as the increase in the global temperature of the oceans, their acidification and the decrease of oxygen. Ocean waters have a thermal inertia and centuries are needed to normalize their temperature and salinity, which affects the survival of many species. This is one of the many signs that the other creatures of this world have stopped being our companions along the way and have become instead our victims.

16. The same can be said about the decrease in the continental ice sheets. The melting of the poles will not be able to be reversed for hundreds of years. As for the climate, there are factors that have persisted for long periods of time, independent of the events that may have triggered them. For this reason, we are now unable to halt the enormous damage we have caused. We barely have time to prevent even more tragic damage.

17. Certain apocalyptic diagnoses may well appear scarcely reasonable or insufficiently grounded. This should not lead us to ignore the real possibility that we are approaching a critical point. Small

changes can cause greater ones, unforeseen and perhaps already irreversible, due to factors of inertia. This would end up precipitating a cascade of events having a snowball effect. In such cases, it is always too late, since no intervention will be able to halt a process once begun. There is no turning back. We cannot state with certainty that all this is going to happen, based on present conditions. But it is certain that it continues to be a possibility, if we take into account phenomena already in motion that "sensitize" the climate, like the reduction of ice sheets, changes in ocean currents, deforestation in tropical rainforests and the melting of permafrost in Russia, etc. [12]

18. Consequently, a broader perspective is urgently needed, one that can enable us to esteem the marvels of progress, but also to pay serious attention to other effects that were probably unimaginable a century ago. What is being asked of us is nothing other than a certain responsibility for the legacy we will leave behind, once we pass from this world.

19. Finally, we can add that the Covid-19 pandemic brought out the close relation of human life with that of other living beings and with the natural environment. But in a special way, it confirmed that what happens in one part of the world has repercussions on the entire planet. This allows me to reiterate two convictions that I repeat over and over again: "Everything is connected" and "No one is saved alone".

2. A Growing Technocratic Paradigm

20. In *Laudato Si'*, I offered a brief resumé of the technocratic paradigm underlying the current process of environmental decay. It is "a certain way of understanding human life and activity [that] has gone awry, to the serious detriment of the world around us". [13] Deep down, it consists in thinking "as if reality, goodness and truth automatically flow from technological and economic power as such". [14] As a logical consequence, it then becomes easy "to accept the idea of infinite or unlimited growth, which proves so attractive to economists, financiers and experts in technology". [15]

21. In recent years, we have been able to confirm this diagnosis, even as we have witnessed a new advance of the above paradigm. Artificial intelligence and the latest technological innovations start with the notion of a human being with no limits, whose abilities and possibilities can be infinitely expanded thanks to technology. In this way, the technocratic paradigm monstrously feeds upon itself.

22. Without a doubt, the natural resources required by technology, such as lithium, silicon and so many others, are not unlimited, yet the greater problem is the ideology underlying an obsession: to increase human power beyond anything imaginable, before which nonhuman reality is a mere resource at its disposal. Everything that exists ceases to be a gift for which we should be thankful, esteem and cherish, and instead becomes a slave, prey to any whim of the human mind and its capacities.

23. It is chilling to realize that the capacities expanded by technology "have given those with the knowledge and especially the economic resources to use them, an impressive dominance over the whole of humanity and the entire world. Never has humanity had such power over itself, yet nothing ensures that it will be used wisely, particularly when we consider how it is currently being used... In whose hands does all this power lie, or will it eventually end up? It is extremely risky for a small part of humanity to have it". [16]

Rethinking our use of power

24. Not every increase in power represents progress for humanity. We need only think of the "admirable" technologies that were employed to decimate populations, drop atomic bombs and annihilate ethnic groups. There were historical moments where our admiration at progress blinded us to the horror of its consequences. But that risk is always present, because "our immense technological development has not been accompanied by a development in human responsibility, values and conscience... We stand naked and exposed in the face of our ever-increasing power, lacking the wherewithal to control it. We have certain superficial mechanisms, but we cannot claim to have a sound ethics, a culture and spirituality genuinely capable of setting limits and teaching clear-minded self-restraint". [17] It is not strange that so great a power in such hands is capable of destroying life, while the mentality proper to the technocratic paradigm blinds us and does not permit us to see this extremely grave problem of present-day humanity.

25. Contrary to this technocratic paradigm, we say that the world that surrounds us is not an object of exploitation, unbridled use and unlimited ambition. Nor can we claim that nature is a mere "setting" in which we develop our lives and our projects. For "we are part of nature, included in it and thus in constant interaction with it", [18] and thus "we [do] not look at the world from without but from within". [19]

26. This itself excludes the idea that the human being is extraneous, a foreign element capable only of harming the environment. Human beings must be recognized as a part of nature. Human life, intelligence and freedom are elements of the nature that enriches our planet, part of its internal workings and its equilibrium.

27. For this reason, a healthy ecology is also the result of interaction between human beings and the environment, as occurs in the indigenous cultures and has occurred for centuries in different regions of the earth. Human groupings have often "created" an environment, [20] reshaping it in some way without destroying it or endangering it. The great present-day problem is that the technocratic paradigm has destroyed that healthy and harmonious relationship. In any event, the indispensable need to move beyond that paradigm, so damaging and destructive, will not be found in a denial of the human being, but include the interaction of natural systems "with social systems". [21]

28. We need to rethink among other things the question of human power, its meaning and its limits. For our power has frenetically increased in a few decades. We have made impressive and awesome technological advances, and we have not realized that at the same time we have turned into highly dangerous beings, capable of threatening the lives of many beings and our own survival. Today it is worth repeating the ironic comment of Solovyov about an "age which was so advanced as to be actually the last one". [22] We need lucidity and honesty in order to recognize in time that our power and the progress we are producing are turning against us. [23]

The ethical goad

29. The ethical decadence of real power is disguised thanks to marketing and false information, useful tools in the hands of those with greater resources to employ them to shape public opinion. With the help of these means, whenever plans are made to undertake a project involving significant changes in the environment or high levels of contamination, one raises the hopes of the people of that area by speaking of the local progress that it will be able to generate or of the potential for economic growth, employment and human promotion that it would mean for their children. Yet in reality there does not seem to be any true interest in the future of these people, since they are not clearly told that the project will result in the clearing of their lands, a decline in the quality of their lives, a desolate and less habitable landscape lacking in life, the joy of community and hope for the future; in addition to the global damage that eventually compromises many other people as well.

30. One need but think of the momentary excitement raised by the money received in exchange for the deposit of nuclear waste in a certain place. The house that one could have bought with that money has turned into a grave due to the diseases that were then unleashed. And I am not saying this, moved by a overflowing imagination, but on the basis of something we have seen. It could be said that this is an extreme example, but in these cases there is no room for speaking of "lesser" damages, for it is precisely the amassing of damages considered tolerable that has brought us to the situation in which we now find ourselves.

31. This situation has to do not only with physics or biology, but also with the economy and the way we conceive it. The mentality of maximum gain at minimal cost, disguised in terms of reasonableness, progress and illusory promises, makes impossible any sincere concern for our common home and any real preoccupation about assisting the poor and the needy discarded by our society. In recent years, we can note that, astounded and excited by the promises of any number of false prophets, the poor themselves at times fall prey to the illusion of a world that is not being built for them.

32. Mistaken notions also develop about the concept of "meritocracy", which becomes seen as a "merited" human power to which everything must be submitted, under the rule of those born with greater possibilities and advantages. A healthy approach to the value of hard work, the

development of one's native abilities and a praiseworthy spirit of initiative is one thing, but if one does not seek a genuine equality of opportunity, "meritocracy" can easily become a screen that further consolidates the privileges of a few with great power. In this perverse logic, why should they care about the damage done to our common home, if they feel securely shielded by the financial resources that they have earned by their abilities and effort?

33. In conscience, and with an eye to the children who will pay for the harm done by their actions, the question of meaning inevitably arises: "What is the meaning of my life? What is the meaning of my time on this earth? And what is the ultimate meaning of all my work and effort?"

3. The Weakness of International Politics

34. Although "our own days seem to be showing signs of a certain regression... each new generation must take up the struggles and attainments of past generations, while setting its sights even higher. This is the path. Goodness, together with love, justice and solidarity, are not achieved once and for all; they have to be realized each day". [24] For there to be solid and lasting advances, I would insist that, "preference should be given to multilateral agreements between States". [25]

35. It is not helpful to confuse multilateralism with a world authority concentrated in one person or in an elite with excessive power: "When we talk about the possibility of some form of world authority regulated by law, we need not necessarily think of a personal authority". [26] We are speaking above all of "more effective world organizations, equipped with the power to provide for the global common good, the elimination of hunger and poverty and the sure defence of fundamental human rights". [27] The issue is that they must be endowed with real authority, in such a way as to "provide for" the attainment of certain essential goals. In this way, there could come about a multilateralism that is not dependent on changing political conditions or the interests of a certain few, and possesses a stable efficacy.

36. It continues to be regrettable that global crises are being squandered when they could be the occasions to bring about beneficial changes. [28] This is what happened in the 2007-2008 financial crisis and again in the Covid-19 crisis. For "the actual strategies developed worldwide in the wake of [those crises] fostered greater individualism, less integration and increased freedom for the truly powerful, who always find a way to escape unscathed". [29]

Reconfiguring multilateralism

37. More than saving the old multilateralism, it appears that the current challenge is to reconfigure and recreate it, taking into account the new world situation. I invite you to recognize that "many groups and organizations within civil society help to compensate for the shortcomings of the international community, its lack of coordination in complex situations, and its lack of attention to

fundamental human rights". [30] For example, the Ottawa Process against the use, production and manufacture of antipersonnel mines is one example that shows how civil society with its organizations is capable of creating effective dynamics that the United Nations cannot. In this way, the principle of subsidiarity is applied also to the global-local relationship.

38. In the medium-term, globalization favours spontaneous cultural interchanges, greater mutual knowledge and processes of integration of peoples, which end up provoking a multilateralism "from below" and not simply one determined by the elites of power. The demands that rise up from below throughout the world, where activists from very different countries help and support one another, can end up pressuring the sources of power. It is to be hoped that this will happen with respect to the climate crisis. For this reason, I reiterate that "unless citizens control political power – national, regional and municipal – it will not be possible to control damage to the environment". [31]

39. Postmodern culture has generated a *new sensitivity* towards the more vulnerable and less powerful. This is connected with my insistence in the Encyclical Letter *Fratelli Tutti* on the primacy of the human person and the defence of his or her dignity beyond every circumstance. It is another way of encouraging multilateralism for the sake of resolving the real problems of humanity, securing before all else respect for the dignity of persons, in such a way that ethics will prevail over local or contingent interests.

40. It is not a matter of replacing politics, but of recognizing that the emerging forces are becoming increasingly relevant and are in fact capable of obtaining important results in the resolution of concrete problems, as some of them demonstrated during the pandemic. The very fact that answers to problems can come from any country, however little, ends up presenting multilateralism as an inevitable process.

41. The old diplomacy, also in crisis, continues to show its importance and necessity. Still, it has not succeeded in generating a model of multilateral diplomacy capable of responding to the new configuration of the world; yet should it be able to reconfigure itself, it must be part of the solution, because the experience of centuries cannot be cast aside either.

42. Our world has become so multipolar and at the same time so complex that a different framework for effective cooperation is required. It is not enough to think only of balances of power but also of the need to provide a response to new problems and to react with global mechanisms to the environmental, public health, cultural and social challenges, especially in order to consolidate respect for the most elementary human rights, social rights and the protection of our common home. It is a matter of establishing global and effective rules that can permit "providing for" this global safeguarding.

43. All this presupposes the development of a new procedure for decision-making and legitimizing

those decisions, since the one put in place several decades ago is not sufficient nor does it appear effective. In this framework, there would necessarily be required spaces for conversation, consultation, arbitration, conflict resolution and supervision, and, in the end, a sort of increased "democratization" in the global context, so that the various situations can be expressed and included. It is no longer helpful for us to support institutions in order to preserve the rights of the more powerful without caring for those of all.

4. Climate Conferences: Progress and Failures

44. For several decades now, representatives of more than 190 countries have met periodically to address the issue of climate change. The 1992 Rio de Janeiro Conference led to the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), a treaty that took effect when the necessary ratification on the part of the signatories concluded in 1994. These States meet annually in the Conference of the Parties (COP), the highest decision-making body. Some of these Conferences were failures, like that of Copenhagen (2009), while others made it possible to take important steps forward, like COP3 in Kyoto (1997). Its significant Protocol set the goal of reducing overall greenhouse gas emissions by 5% with respect to 1990. The deadline was the year 2012, but this, clearly, was not achieved.

45. All parties also committed themselves to implementing programmes of adaptation in order to reduce the effects of climate change now taking place. Provisions were also made for aid to cover the costs of the measures in developing countries. The Protocol actually took effect in 2005.

46. Afterwards, it was proposed to create a mechanism regarding the loss and damage caused by climate change, which recognizes as those chiefly responsible the richer countries and seeks to compensate for the loss and damage that climate change produces in the more vulnerable countries. It was not yet a matter of financing the "adaptation" of those countries, but of compensating them for damage already incurred. This question was the subject of important discussions at various Conferences.

47. COP21 in Paris (2015) represented another significant moment, since it generated an agreement that involved everyone. It can be considered as a new beginning, given the failure to meet the goals previously set. The agreement took effect on 4 November 2016. Albeit a binding agreement, not all its dispositions are obligations in the strict sense, and some of them leave ample room for discretion. In any case, properly speaking, there are no provisions for sanctions in the case of unfulfilled commitments, nor effective instruments to ensure their fulfilment. It also provides for a certain flexibility in the case of developing countries.

48. The Paris Agreement presents a broad and ambitious objective: to keep the increase of average global temperatures to under 2° C with respect to preindustrial levels, and with the aim of decreasing them to 1.5° C. Work is still under way to consolidate concrete procedures for

monitoring and to facilitate general criteria for comparing the objectives of the different countries. This makes it difficult to achieve a more objective (quantitative) evaluation of the real results.

49. Following several Conferences with scarce results, and the disappointment of COP25 in Madrid (2019), it was hoped that this inertia would be reversed at COP26 in Glasgow (2021). In effect, its result was to relaunch the Paris Agreement, put on hold by the overall effects of the pandemic. Furthermore, there was an abundance of "recommendations" whose actual effect was hardly foreseeable. Proposals tending to ensure a rapid and effective transition to alternative and less polluting forms of energy made no progress.

50. COP27 in Sharm El Sheikh (2022) was from the outset threatened by the situation created by the invasion of Ukraine, which caused a significant economic and energy crisis. Carbon use increased and everyone sought to have sufficient supplies. Developing countries regarded access to energy and prospects for development as an urgent priority. There was an evident openness to recognizing the fact that combustible fuels still provide 80% of the world's energy, and that their use continues to increase.

51. This Conference in Egypt was one more example of the difficulty of negotiations. It could be said that at least it marked a step forward in consolidating a system for financing "loss and damage" in countries most affected by climate disasters. This would seem to give a new voice and a greater role to developing countries. Yet here too, many points remained imprecise, above all the concrete responsibility of the countries that have to contribute.

52. Today we can continue to state that, "the accords have been poorly implemented, due to lack of suitable mechanisms for oversight, periodic review and penalties in cases of noncompliance. The principles which they proclaimed still await an efficient and flexible means of practical implementation". [32] Also, that "international negotiations cannot make significant progress due to positions taken by countries which place their national interests above the global common good. Those who will have to suffer the consequences of what we are trying to hide will not forget this failure of conscience and responsibility". [33]

5. What to Expect from COP28 in Dubai?

53. The United Arab Emirates will host the next Conference of the Parties (COP28). It is a country of the Persian Gulf known as a great exporter of fossil fuels, although it has made significant investments in renewable energy sources. Meanwhile, gas and oil companies are planning new projects there, with the aim of further increasing their production. To say that there is nothing to hope for would be suicidal, for it would mean exposing all humanity, especially the poorest, to the worst impacts of climate change.

54. If we are confident in the capacity of human beings to transcend their petty interests and to

think in bigger terms, we can keep hoping that COP28 will allow for a decisive acceleration of energy transition, with effective commitments subject to ongoing monitoring. This Conference can represent a change of direction, showing that everything done since 1992 was in fact serious and worth the effort, or else it will be a great disappointment and jeopardize whatever good has been achieved thus far.

55. Despite the many negotiations and agreements, global emissions continue to increase. Certainly, it could be said that, without those agreements, they would have increased even more. Still, in other themes related to the environment, when there was a will, very significant results were obtained, as was the case with the protection of the ozone layer. Yet, the necessary transition towards clean energy sources such as wind and solar energy, and the abandonment of fossil fuels, is not progressing at the necessary speed. Consequently, whatever is being done risks being seen only as a ploy to distract attention.

56. We must move beyond the mentality of appearing to be concerned but not having the courage needed to produce substantial changes. We know that at this pace in just a few years we will surpass the maximum recommended limit of 1.5° C and shortly thereafter even reach 3° C, with a high risk of arriving at a critical point. Even if we do not reach this point of no return, it is certain that the consequences would be disastrous and precipitous measures would have to be taken, at enormous cost and with grave and intolerable economic and social effects. Although the measures that we can take now are costly, the cost will be all the more burdensome the longer we wait.

57. I consider it essential to insist that "to seek only a technical remedy to each environmental problem which comes up is to separate what is in reality interconnected and to mask the true and deepest problems of the global system". [34] It is true that efforts at adaptation are needed in the face of evils that are irreversible in the short term. Also some interventions and technological advances that make it possible to absorb or capture gas emissions have proved promising. Nonetheless, we risk remaining trapped in the mindset of pasting and papering over cracks, while beneath the surface there is a continuing deterioration to which we continue to contribute. To suppose that all problems in the future will be able to be solved by new technical interventions is a form of homicidal pragmatism, like pushing a snowball down a hill.

58. Once and for all, let us put an end to the irresponsible derision that would present this issue as something purely ecological, "green", romantic, frequently subject to ridicule by economic interests. Let us finally admit that it is a human and social problem on any number of levels. For this reason, it calls for involvement on the part of all. In Conferences on the climate, the actions of groups negatively portrayed as "radicalized" tend to attract attention. But in reality they are filling a space left empty by society as a whole, which ought to exercise a healthy "pressure", since every family ought to realize that the future of their children is at stake.

59. If there is sincere interest in making COP28 a historic event that honours and ennobles us as

human beings, then one can only hope for binding forms of energy transition that meet three conditions: that they be efficient, obligatory and readily monitored. This, in order to achieve the beginning of a new process marked by three requirements: that it be drastic, intense and count on the commitment of all. That is not what has happened so far, and only a process of this sort can enable international politics to recover its credibility, since only in this concrete manner will it be possible to reduce significantly carbon dioxide levels and to prevent even greater evils over time.

60. May those taking part in the Conference be strategists capable of considering the common good and the future of their children, more than the short-term interests of certain countries or businesses. In this way, may they demonstrate the nobility of politics and not its shame. To the powerful, I can only repeat this question: "What would induce anyone, at this stage, to hold on to power, only to be remembered for their inability to take action when it was urgent and necessary to do so?" [35]

6. Spiritual Motivations

61. I cannot fail in this regard to remind the Catholic faithful of the motivations born of their faith. I encourage my brothers and sisters of other religions to do the same, since we know that authentic faith not only gives strength to the human heart, but also transforms life, transfigures our goals and sheds light on our relationship to others and with creation as a whole.

In the light of faith

62. The Bible tells us: "God saw everything that he had made, and indeed, it was very good" (*Gen* 1:31). His is "the earth with all that is in it" (*Deut* 10:14). For this reason, he tells us that, "the land shall not be sold in perpetuity, for the land is mine; with me you are but aliens and tenants" (*Lev* 25:23). Hence, "responsibility for God's earth means that human beings, endowed with intelligence, must respect the laws of nature and the delicate equilibria existing between the creatures of this world". [36]

63. At the same time, "the universe as a whole, in all its manifold relationships, shows forth the inexhaustible richness of God". Hence, to be wise, "we need to grasp the variety of things in their multiple relationships". [37] Along this path of wisdom, it is not a matter of indifference to us that so many species are disappearing and that the climate crisis endangers the life of many other beings.

64. Jesus "was able to invite others to be attentive to the beauty that there is in the world because he himself was in constant touch with nature, lending it an attraction full of fondness and wonder. As he made his way throughout the land, he often stopped to contemplate the beauty sown by his Father, and invited his disciples to perceive a divine message in things". [38]

65. Hence, "the creatures of this world no longer appear to us under merely natural guise,

because the risen One is mysteriously holding them to himself and directing them towards fullness as their end. The very flowers of the field and the birds which his human eyes contemplated and admired are now imbued with his radiant presence". [39] If "the universe unfolds in God, who fills it completely... there is a mystical meaning to be found in a leaf, in a mountain trail, in a dewdrop, in a poor person's face". [40] The world sings of an infinite Love: how can we fail to care for it?

Journeying in communion and commitment

66. God has united us to all his creatures. Nonetheless, the technocratic paradigm can isolate us from the world that surrounds us and deceive us by making us forget that the entire world is a "contact zone". [41]

67. The Judaeo-Christian vision of the cosmos defends the unique and central value of the human being amid the marvellous concert of all God's creatures, but today we see ourselves forced to realize that it is only possible to sustain a "situated anthropocentrism". To recognize, in other words, that human life is incomprehensible and unsustainable without other creatures. For "as part of the universe... all of us are linked by unseen bonds and together form a kind of universal family, a sublime communion which fills us with a sacred, affectionate and humble respect". [42]

68. This is not a product of our own will; its origin lies elsewhere, in the depths of our being, since "God has joined us so closely to the world around us that we can feel the desertification of the soil almost as a physical ailment, and the extinction of a species as a painful disfigurement". [43] Let us stop thinking, then, of human beings as autonomous, omnipotent and limitless, and begin to think of ourselves differently, in a humbler but more fruitful way.

69. I ask everyone to accompany this pilgrimage of reconciliation with the world that is our home and to help make it more beautiful, because that commitment has to do with our personal dignity and highest values. At the same time, I cannot deny that it is necessary to be honest and recognize that the most effective solutions will not come from individual efforts alone, but above all from major political decisions on the national and international level.

70. Nonetheless, every little bit helps, and avoiding an increase of a tenth of a degree in the global temperature would already suffice to alleviate some suffering for many people. Yet what is important is something less quantitative: the need to realize that there are no lasting changes without cultural changes, without a maturing of lifestyles and convictions within societies, and there are no cultural changes without personal changes.

71. Efforts by households to reduce pollution and waste, and to consume with prudence, are creating a new culture. The mere fact that personal, family and community habits are changing is contributing to greater concern about the unfulfilled responsibilities of the political sectors and indignation at the lack of interest shown by the powerful. Let us realize, then, that even though this

does not immediately produce a notable effect from the quantitative standpoint, we are helping to bring about large processes of transformation rising from deep within society.

72. If we consider that emissions per individual in the United States are about two times greater than those of individuals living in China, and about seven times greater than the average of the poorest countries, [44] we can state that a broad change in the irresponsible lifestyle connected with the Western model would have a significant long-term impact. As a result, along with indispensable political decisions, we would be making progress along the way to genuine care for one another.

73. "Praise God" is the title of this letter. For when human beings claim to take God's place, they become their own worst enemies.

Given in Rome, at the Basilica of Saint John Lateran, on 4 October, the Feast of Saint Francis of Assisi, in the year 2023, the eleventh of my Pontificate.

FRANCIS

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[4] Cf. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2021, The Physical Science Basis*, Cambridge and New York, 2021, B.2.2.

[5] Cf. ID., *Climate Change 2023, Synthesis Report, Summary for Policymakers*, B.3.2. For the 2023 Report, see https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.

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[9] Cf. ibid., B.5.3.

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[12] Cf. ibid.

[13] Encyclical Letter *Laudato Si'* (24 May 2015), 101: AAS 107 (2015), 887.

[14] Ibid., 105: AAS 107 (2015), 889.

[15] Ibid. 106: AAS 107 (2015), 890.

[16] Ibid., 104: AAS 107 (2015), 888-889.

[17] Ibid., 105: AAS 107 (2015), 889.

[18] Ibid., 139: AAS 107 (2015), 903.

[19] Ibid., 220: AAS 107 (2015), 934.

[20] Cf. S. SÖRLIN-P. WARDE, *"Making the Environment Historical. An Introduction"*, in S. SÖRLIN-P. WARDE, eds., *Nature's End: History and the Environment*, Basingstroke-New York, 2009, 1-23.

[21] Encyclical Letter *Laudato Si'* (24 May 2015), 139: AAS 107 (2015), 903.

[22] Cf. *War, Progress and the End of History, Including a Short Story of the Anti-Christ. Three Discussions by Vladimir Soloviev*, London, 1915, p. 197.

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[24] Encyclical Letter *Fratelli Tutti* (3 October 2020), 11: AAS 112 (2020), 972.

[25] Ibid., 174: AAS 112 (2020), 1030.

[26] Ibid., 172: AAS 112 (2020), 1029.

[27] Ibid.

[28] Cf. ibid., 170: AAS 112 (2020), 1029.

[29] Ibid.

[30] Ibid., 175: AAS 112 (2020), 1031.

[31] Encyclical Letter *Laudato Si'* (24 May 2015), 179: AAS 107 (2015), 918.

[32] Ibid., 167: AAS 107 (2015), 914.

[33] Ibid., 169: AAS 107 (2015), 915.

[34] Ibid., 111: AAS 107 (2015), 982.

[35] Ibid., 57: AAS 107 (2015), 870.

[36] Ibid., 68: AAS 107 (2015), 874.

[37] Ibid., 86: AAS 107 (2015), 881.

[38] Ibid., 97: AAS 107 (2015), 886.

[39] Ibid., 100: AAS 197 (2015), 887.

[40] Ibid., 233: AAS 107 (2015), 938.

[41] Cf. D. J. HARAWAY, *When Species Meet*, Minneapolis, 2008, pp. 205-249.

[42] Encyclical Letter *Laudato Si'* (24 May 2015), 89: AAS 107 (2015), 883.

[43] Apostolic Exhortation *Evangelii Gaudium* (24 November 2013), 215: AAS 105 (2013), 1109.

[44] Cf. UNITED NATIONS ENVIRONMENT PROGRAM, *The Emissions Gap Report 2022: https://www.unep.org/resources/emissions-gap-report-2022.*