Global Climate Change, Plant Biology and Public Health.

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Thanks to:
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James Straka, PhD, Macalester College, St. Paul, MN
David Frenz, MD, the Bethesda Clinic, St. Paul, MN
Jonathan Patz, MD Johns Hopkins, Baltimore, MD
Dennis Gebhard, Multidata Inc., St. Paul, MN
Paul Epstein, MD, Harvard, Boston, MA
Atmospheric CO$_2$

Why is carbon dioxide going up? Are humans an influence? So CO$_2$ is going up and humans are responsible. So what?
So what if CO₂ goes up? Part I. Indirect impacts.

<table>
<thead>
<tr>
<th>Gas</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N₂)</td>
<td>78.1</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>20.1</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>0.93</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>0.038</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td>0.05 to 1</td>
</tr>
</tbody>
</table>

No H₂O and CO₂? Surface temperature would be –18°C. With H₂O and CO₂? Surface temperature is 15°C. Adding H₂O or CO₂ reduces the amount of heat leaving the atmosphere.
If water vapor is high, it will be the dominant warming gas....little effect of CO$_2$.

If water vapor is low, adding CO$_2$ will increase the surface temperature.
What are the effects of warming on public health?

- Changes in range of insect or rodent borne diseases.
- Changes in water or seafood borne diseases.
- Increasing ground-level ozone, and respiratory ailments.
- Contamination of drinking water due to excessive flooding.
- Heat-related deaths / fewer cold related.
So what if CO$_2$ goes up?, Part II, direct impacts

Carbon dioxide is the source of carbon for photosynthesis, and consequently for 99% of all life.

CO$_2$ + H$_2$O + light $\rightarrow$ O$_2$ + organic C + chemical energy
Plants are important

90% of all living biomass is plant material. Plant growth is dependent on four resources:

Sunlight, nutrients, water and carbon dioxide.

Plants evolved at a time when atmospheric CO₂ was much higher than it is today. Consequently, the increase in atmospheric CO₂ represents a very rapid change in a needed resource. Increasing it will result in the overall stimulation of plant growth up to 1000 ppm.
But isn’t more plant growth desirable?

“We are living in an increasingly lush environment of plants and animals as a result of the carbon dioxide increase. This is a wonderful and unexpected gift from the industrial revolution.”

WSJ
Two assumptions:

1. That all plants will respond equally and competition will be unaffected.

2. All plants are equally desirable. (i.e. “green is good”).
If CO₂ stimulates plant growth, can we use it to boost crop yields? Is there variation within a crop to CO₂?

Rice

<table>
<thead>
<tr>
<th>Variety</th>
<th>Graphical Representation</th>
<th>Temperature</th>
<th>CO₂ Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAC 165*</td>
<td></td>
<td>29/21°C</td>
<td>X = 48%</td>
</tr>
<tr>
<td>YRL39*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 64*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinandang Patong*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 36*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 72*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRAT 104*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS4*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azucena*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 46*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MGL-2*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 28*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salumpikit*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR 74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ITA 186</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soybean

<table>
<thead>
<tr>
<th>Variety</th>
<th>Graphical Representation</th>
<th>Temperature</th>
<th>CO₂ Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANDARIN</td>
<td></td>
<td></td>
<td>X = 40.5%</td>
</tr>
<tr>
<td>WILLIAMS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MANCHU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HARROW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MUKDEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARKSOY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUNFIELD</td>
<td></td>
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</tbody>
</table>

But not all plants are beneficial.
How can plants affect public health?
Some direct effects:

- **Allergies / Asthma:**
- **Contact dermatitis:**
- **Poison/Toxicology:**
1. CO₂, plants and allergies

**Principle Fall Allergen**

~35 million sufferers

Common ragweed.
Determining Ragweed Pollen Production

Sampling pollen from ragweed catkins.
Response of common ragweed to CO$_2$

- **Pollen Production**
  - 280 ppm: 4.8 g
  - 370 ppm: 10.9 g*
  - 600 ppm: 20.5 g*

- **Antigen Amb a1 ELISA / mg protein**
  - 280 ppm: 4490
  - 370 ppm: 5290
  - 600 ppm: 8180*

Chamber Study, USDA
*Functional Plant Biology 27:893-898*
*Functional Plant Biology 32:667-670*
Fungal decomposition of plants.

*Alternaria alternata* has been associated with a number of respiratory problems such as rhinitis, asthma, allergic dermatitis and allergic sinusitis. The spores are the cause of the allergic reactions.

For timothy grass grown from 300-600 ppm CO$_2$, rising carbon dioxide levels results in reduced leaf N levels. Initial data suggest that this could, in turn, increase the rate of sporulation.
2. CO$_2$, plants and contact dermatitis

Can rising CO$_2$ alter the growth or toxicity of poison ivy?
The Duke University FACE Site: State of the Art.
Poison ivy at Duke Face ring.
Poison ivy plants grow faster at elevated CO₂
Poison ivy allergenicity

Duke University, USDA study, *PNAS* 103:9086-9089
3. CO$_2$, plants and poison

Castor bean (Ricinus communis), produces ricin, one of the deadliest poisons known to man. Increasing CO$_2$ by 300 ppm results in a 34% increase in photosynthesis (Grimer and Komor 1999).
How can plants affect public health?

Some indirect effects:

• Nutritional changes.
• Medicines / Narcotics.
• Disease vector biology.
• Pesticide use.
CO₂ and human nutrition.

% Flour protein from wheat lines released during the 20th century.

Recent cooperative work with NIH indicates an increase in omega-3-fatty acids in mung bean with rising CO₂.
### 2a. CO₂, plants and medicine

<table>
<thead>
<tr>
<th>Drug</th>
<th>Action/Clinical Use</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetyldigoxin</td>
<td>Cardiotonic</td>
<td>Digitalis lanata</td>
</tr>
<tr>
<td>Allyl isothiocyanate</td>
<td>Rubefacient</td>
<td>Brassica nigra</td>
</tr>
<tr>
<td>Atropine</td>
<td>Anticholinergic</td>
<td>Atropa belladonna</td>
</tr>
<tr>
<td>Berberine</td>
<td>Bacillary dysentery</td>
<td>Berberis vulgaris</td>
</tr>
<tr>
<td>Codeine</td>
<td>Analgesic, antitussive</td>
<td>Papaver somniferum</td>
</tr>
<tr>
<td>Danthon</td>
<td>Laxative</td>
<td>Cassia spp.</td>
</tr>
<tr>
<td>L-Dopa</td>
<td>Anti-Parkinson</td>
<td>Mucuna spp.</td>
</tr>
<tr>
<td>Digitoxin</td>
<td>Cardiotonic</td>
<td>Digitalis purpurea</td>
</tr>
<tr>
<td>Ephedrine</td>
<td>Antihistamine</td>
<td>Ephedra sinica</td>
</tr>
<tr>
<td>Galanthamine</td>
<td>Cholinesterase inhibitor</td>
<td>Lycoris squamigera</td>
</tr>
<tr>
<td>Kawain</td>
<td>Tranquilizer</td>
<td>Piper methysticum</td>
</tr>
<tr>
<td>Lapachol</td>
<td>Anti-cancer, anti-tumor</td>
<td>Tabebuia spp.</td>
</tr>
<tr>
<td>Ouabain</td>
<td>Cardiotonic</td>
<td>Strophanthus gratus</td>
</tr>
<tr>
<td>Quinine</td>
<td>Anti-malarial</td>
<td>Cinchona ledgeriana</td>
</tr>
<tr>
<td>Salicin</td>
<td>Analgesic</td>
<td>Salix alba</td>
</tr>
<tr>
<td>Taxol</td>
<td>Anti-tumor</td>
<td>Podophyllum peltatum</td>
</tr>
<tr>
<td>Vasicine</td>
<td>Cerebral stimulant</td>
<td>Vinca minor</td>
</tr>
<tr>
<td>Vincristine</td>
<td>Anti-leukemic agent</td>
<td>Catharanthus roseus</td>
</tr>
</tbody>
</table>

Approximately 15% of all current pharmaceuticals in developed countries are derived solely from plants (85% in undeveloped countries).
Alkaloids derived from plants

Atropine

Caffeine

Cocaine

Codeine

Morphine

Nicotine

Scopolamine

Thebaine
Atropine and scopolamine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Averages</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>294</td>
<td>378</td>
</tr>
<tr>
<td>Jimson weed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atropine (mg)</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Atropine (mg)</td>
<td>11.9</td>
<td>14.7</td>
</tr>
<tr>
<td>Scopolamine (mg)</td>
<td>1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Scopolamine (mg)</td>
<td>12.9</td>
<td>20.9</td>
</tr>
</tbody>
</table>

(*) P<0.10; *, P<0.05; **, P<0.01; ***, P<0.001
2b. CO₂, plants and narcotics.

Effects unknown

Growth increases.

Anecdotal evidence
Papaver setigerum DC. (Wild poppy)

Quantify growth and alkaloid production to carbon dioxide

- 300 ppm ~1950
- 400 ppm Current
- 500 ppm ~2050
- 600 ppm ~2090
P. setigerum is sensitive to even small (100 ppm) increases in carbon dioxide.

Greatest relative stimulation has occurred with recent (last few decades) CO$_2$ increase.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Averages</th>
<th>P-value</th>
<th></th>
<th></th>
<th>CO₂ Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Capsule No.</td>
<td>14.6</td>
<td>29.4</td>
<td>32.9</td>
<td>52.1</td>
<td>***</td>
</tr>
<tr>
<td>Capsule Wt. (g)</td>
<td>1.44</td>
<td>2.47</td>
<td>3.55</td>
<td>4.30</td>
<td>***</td>
</tr>
<tr>
<td>Latex (mg)</td>
<td>97</td>
<td>198</td>
<td>259</td>
<td>363</td>
<td>***</td>
</tr>
<tr>
<td>Morphine (%)</td>
<td>2.20</td>
<td>2.34</td>
<td>2.56</td>
<td>2.67</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Concentration of other alkaloids did not increase with increasing CO₂.
3-4 x increase in alkaloid production in wild poppy with recent and projected CO₂ increases.
Nicotine production

Nicotine Concentration

294 ppm  4.7 µg g\(^{-1}\)
378 ppm  4.4 µg g\(^{-1}\)
690 ppm  3.6 µg g\(^{-1}\)
3. CO$_2$, plants and disease vectors

Plants are not vectors per se, but:

$\text{CO}_2 / \text{temperature}$
4. CO$_2$, plants and pesticides.

Why can’t we just control these weeds?

As carbon dioxide increases, glyphosate efficacy is reduced
A synopsis of CO₂ impacts on herbicide efficacy

Efficacy is reduced in a number of studies. The basis for the reduction is not entirely known.
Climate change, plants and public health

**Direct Effects**
- Allergies
- Contact dermatitis
- Toxicology

**Indirect Effects**
- Nutrition
- Medicine
- Spread of disease vectors
- Increased pesticide use.
Prove me wrong…

All this is “blue-sky” hypothetical &*^$%# anyway. It won’t happen in real-life, and even if it does, temperature and carbon dioxide effects are a long ways away.

Mauna Loa, “Official” CO₂ data.

10,000 feet on a mountaintop in Hawaii.

Crazy Liberals!
Is the rise in CO$_2$ the same everywhere?

- Change in average day-time CO$_2$ concentration (ppm) from downtown Baltimore to an organic (rural) farm.

<table>
<thead>
<tr>
<th>Location</th>
<th>CO$_2$ Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm</td>
<td>386.2</td>
</tr>
<tr>
<td>Park</td>
<td>402.2</td>
</tr>
<tr>
<td>City</td>
<td>455.5</td>
</tr>
</tbody>
</table>

D'OH!
Is the increase in temperature the same?

- Change in average daily temperature (°C) from downtown Baltimore to an organic (rural) farm (2002).
And if it isn’t…Can we study the effects of climate change **NOW**?

Placing four 2x2 m² plots
Near downtown Baltimore.
Use same soil and seed bank in suburban and rural locations.

“Necessity may be the mother of invention, poverty is the father….”
First year response, rural farm, 2002

First year re-growth of fallow soil, +90% lambsquarters, 6-8 feet in height.

(About as big as it gets)
First year response, urban Baltimore, 2002

First year re-growth, 80% lambsquarters, 10-12 feet in height. More annual weeds present.

No other meteorological factors (wind speed, ozone, etc.) varied along the transect.

Got ragweed?

![Graph showing ragweed pollen levels over the year in different locations]
Ragweed persistence 2001-2005

- Urban
- Suburban
- Rural
And after 5 years………..

Rural

Urban

Ragweed populations have diminished in urban locations, but trees (another important source of pollen) have compensated!
Litter deposition and seed germination.

Greater litter deposition from the urban site (high carbon dioxide, temperature) prevents germination of small seeded annuals (e.g. ragweed), while promoting larger seeded (usually perennial) species.
Weeds and Public Health: Real Time:
But I still see ragweed in the city. What’s up with that?
Some tentative conclusions: allergies

Ragweed, in the chamber, in monocultures, in competition, shows a strong initial response to CO₂ and/or temperature. This suggests that ragweed has—and may continue—to show a strong temporal response to rising CO₂ and/or temperature associated with climate change.

With respect to urbanization, while initial growth and pollen production is high following a disturbance, population persistence may be shortened due to CO₂/temperature induced changes in litter deposition and the rate of succession. Yet higher rates of soil disturbance may allow for continuous ragweed populations. What is the rate of soil disturbance? What other species will show an increase in pollen? What about plant decomposition and sporulation?
Poison ivy in the forest shows a disproportionate increase in growth rate with future levels of carbon dioxide.

These increases in growth rate are concurrent with qualitative changes in urushiol that are likely to increase the incidence of contact dermatitis.

Would poison ivy growing in an urban environment already show a similar response? What other species might be affected? Can urushiol be used in oncology?
Some tentative conclusions: toxicology

Difficult to make any. Very little data. Likely that CO$_2$ will affect the concentration of poisonous compounds.
Some tentative conclusions: human nutrition.

In general, the ratio of carbon:nitrogen increases as carbon dioxide increases, with a subsequent decrease in protein concentration.

Likely to be a multitude of effects, some positive, some negative.

Which qualitative factors related to nutrition are likely to change? What patterns can we discern? Only a handful of studies.
Some tentative conclusions: Plants and Medicines

Plants are a major source of medicines—new and old.

Rising carbon dioxide and/or temperature will alter the concentration and production of these medicines.

Similar changes can be expected for narcotic plants.

How will this change drug efficacy? How will this alter our ability to control or regulate narcotics?
Some tentative conclusions: CO$_2$, plants and disease vectors.

Food supply for rodents or mosquitoes will determine where they can remain viable. Direct effects of CO$_2$ on the quantity and quality of these plants, as well as climatic effects on their distribution will influence disease vectors in, as yet, unpredictable fashion.
Some tentative conclusions: Pesticide use

Herbicides are the most frequently used chemicals in the United States. Alteration of their efficacy by carbon dioxide or temperature will only be overcome by increasing concentration or application. This may have significant effects on residual chemicals in the environment.

What other pesticides are likely to change? Will climate uncertainty necessitate more frequent spraying?
Recognition
Assessment
Research
Adaptation

Science

POLITICS
Walt Kelly (1913-1971)
(To his children)

There is no need to sally forth, for it remains true that those things which make us human are, curiously enough, always close at hand.

Resolve then, that on this very ground, with small flags waving and tinny blast on tiny trumpets, we shall meet the enemy,

and not only may he be ours………. 
...he may be us.