

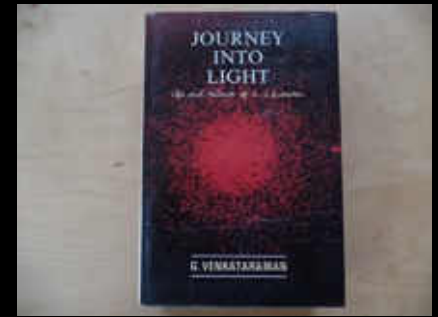
# Global science for global well-being

Thalappil Pradeep  
IIT Madras



Earthrise, taken on December 24, 1968, by Apollo 8 astronaut William Andres.

Nature photographer Galen Rowell declared it "the most influential environmental photograph ever taken".



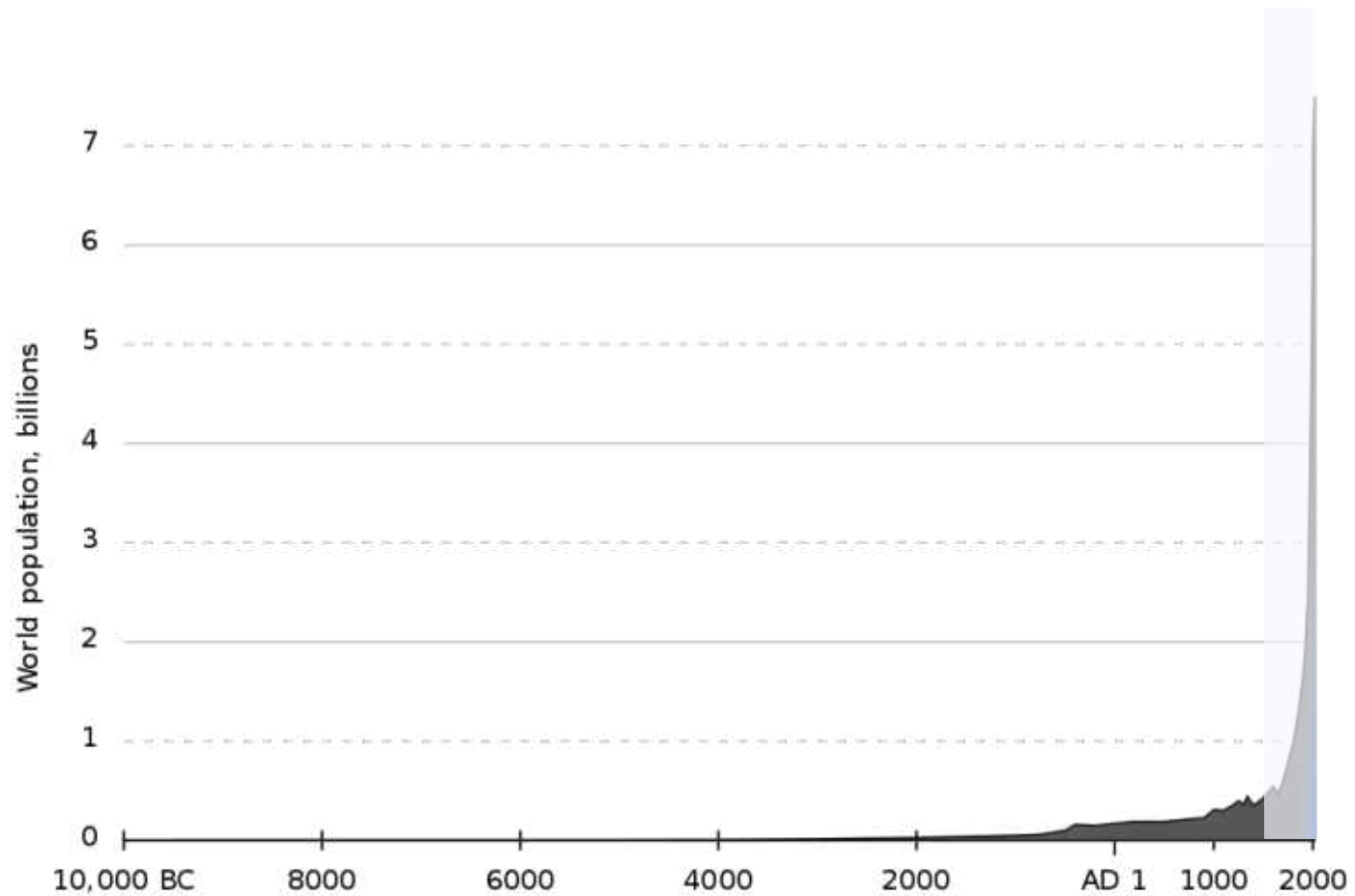
# Global science – why now?



“Pale blue dot” Voyager 1 Feb. 14, 1990

From Wikipedia

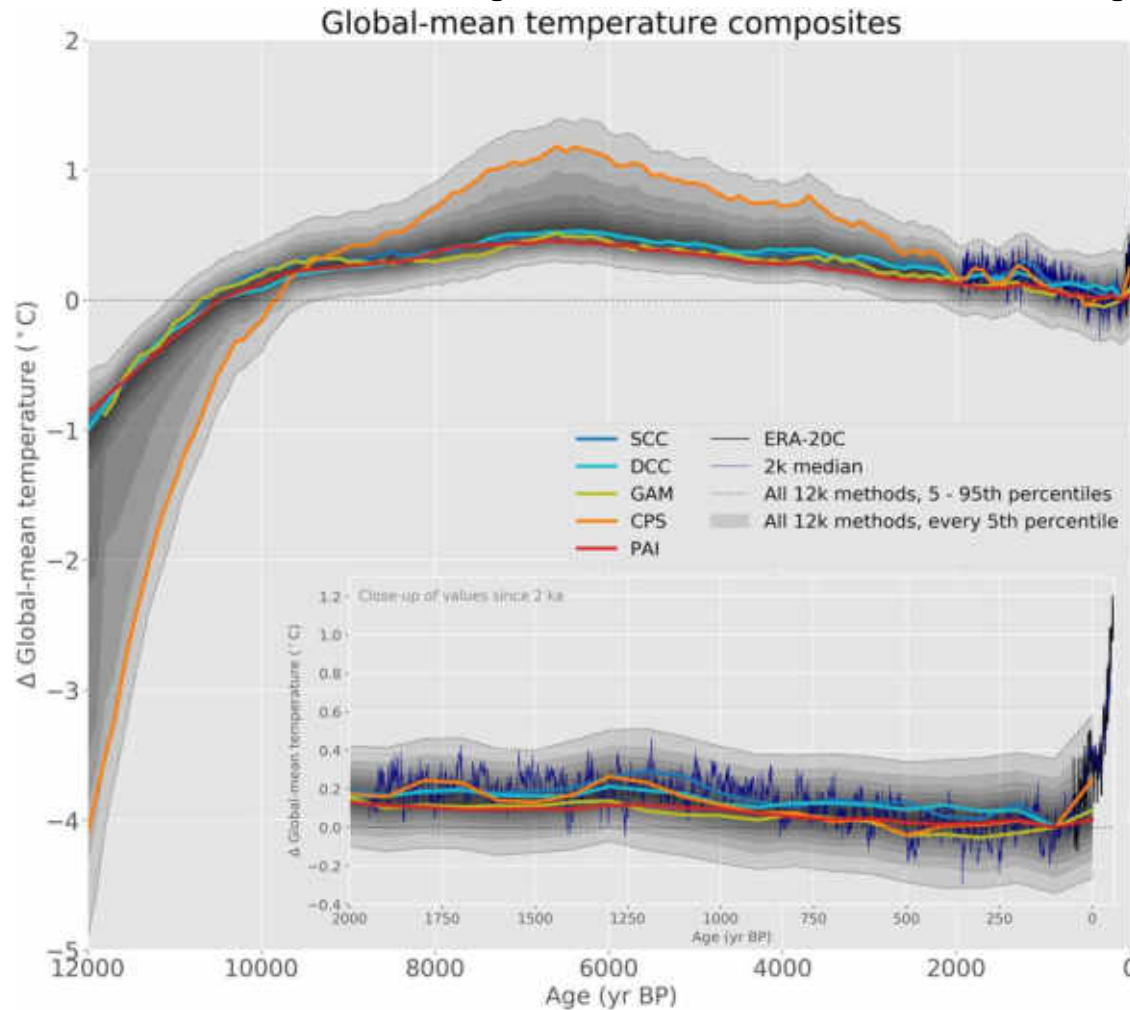
# World population



Wikipedia

Galileo Galilei 1589-92

# The Holocene Epoch – The triumph of man

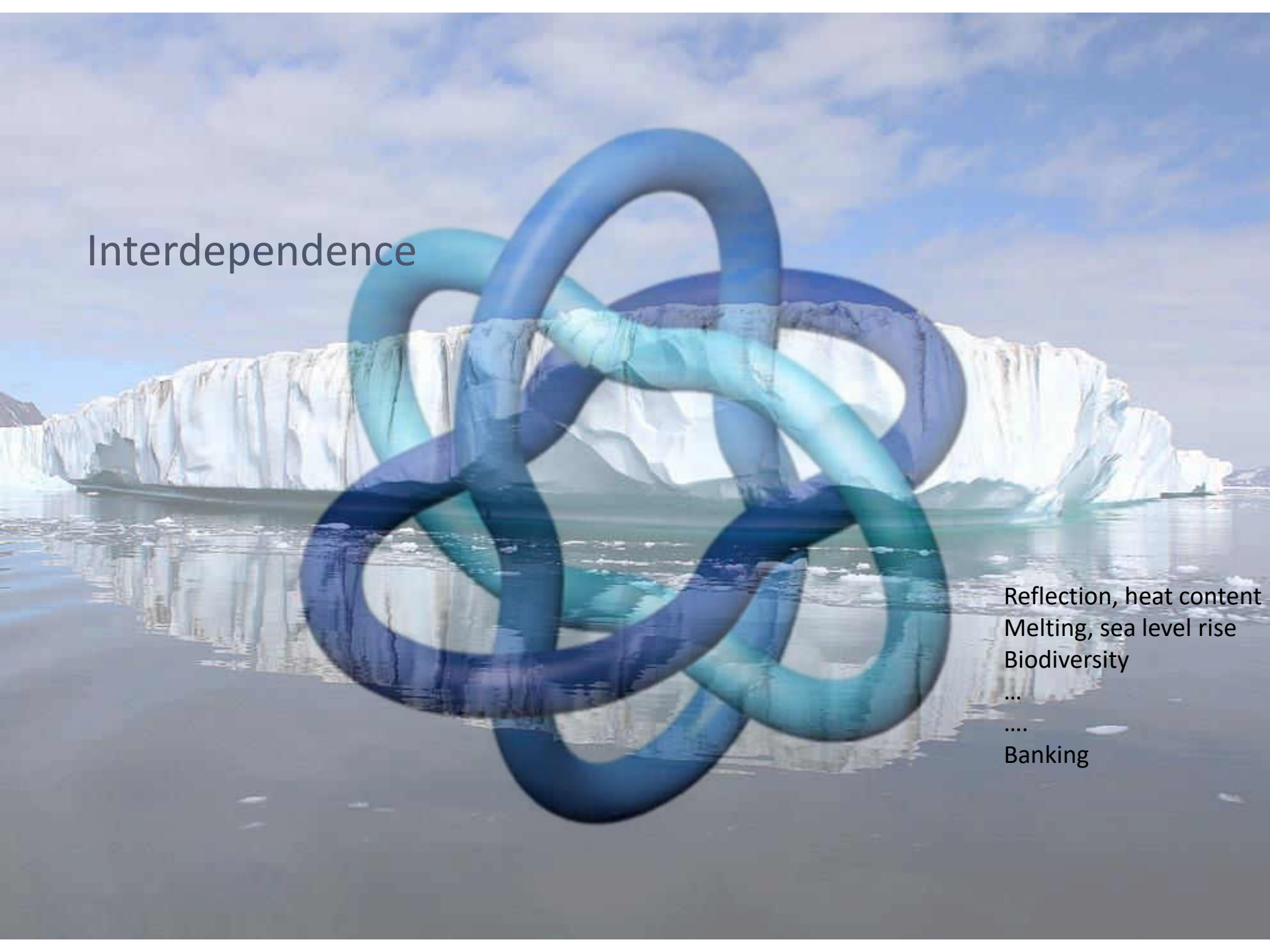


Global mean surface temperature from the Temperature 12k database using different reconstruction methods. The black line is instrumental data for 1900–2010 from the ERA-20C reanalysis product. The inset displays an enlarged view of the past 2000 years.

Darrell Kaufman et al. [Scientific Data](#) volume 7, Article number: 201 (2020)

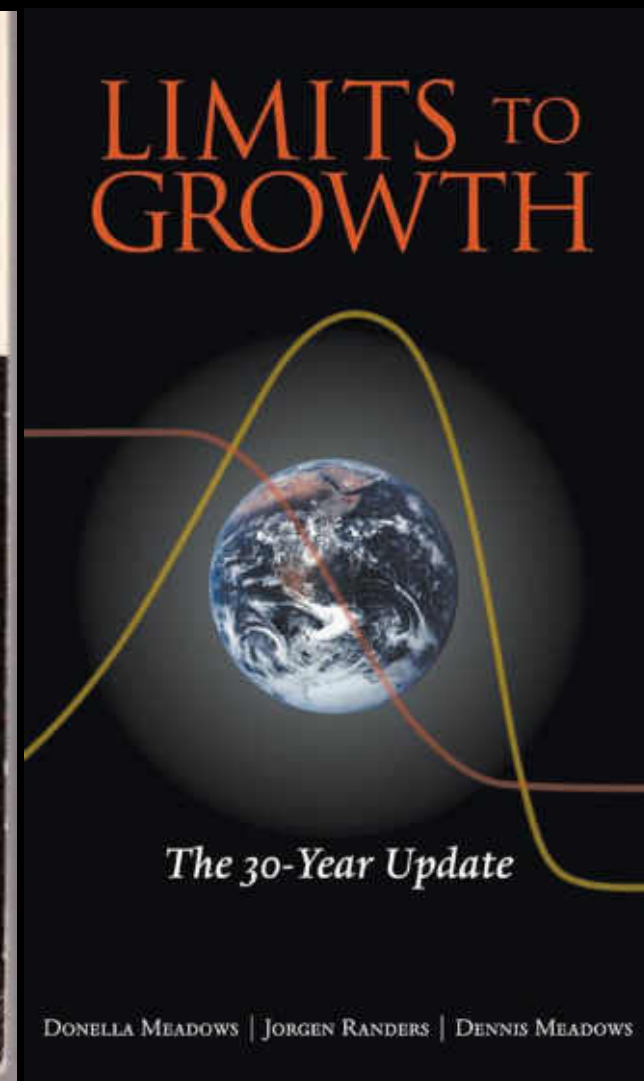
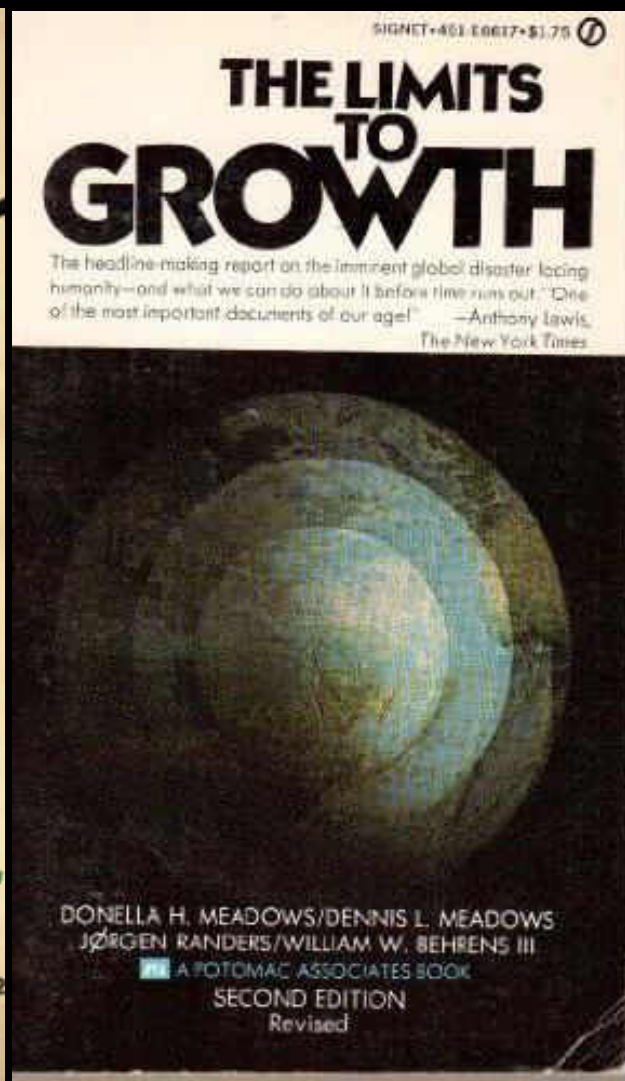
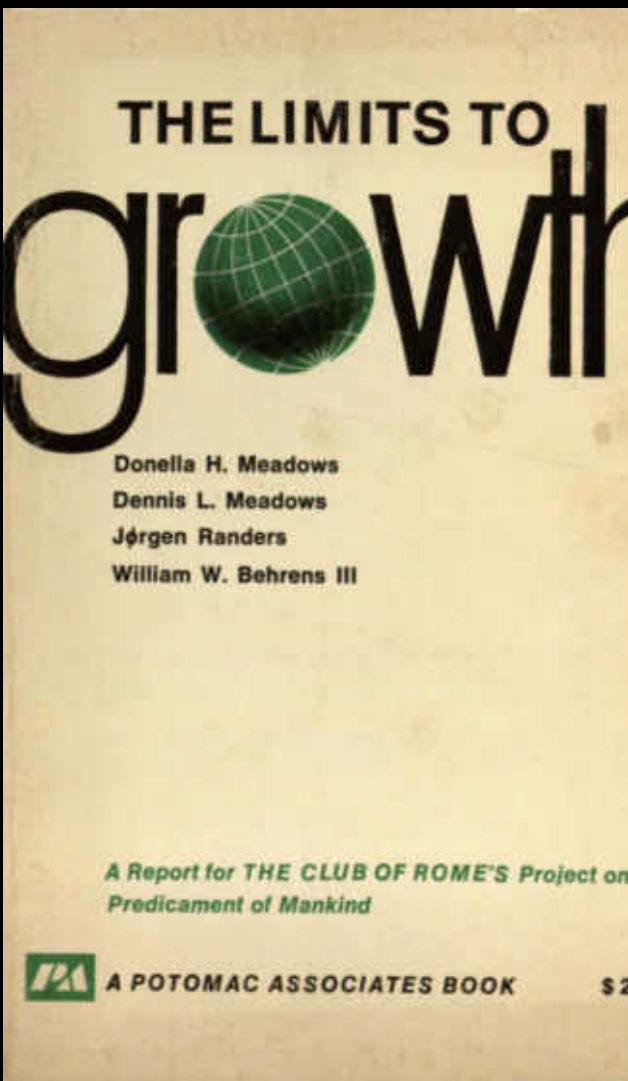
The control over carbon emissions by developed countries is probably not the reason for the globe's survival, but the lack of development in less-developed countries is, according to the Intergovernmental Panel on Climate Change (IPCC). 2014

# Interdependence



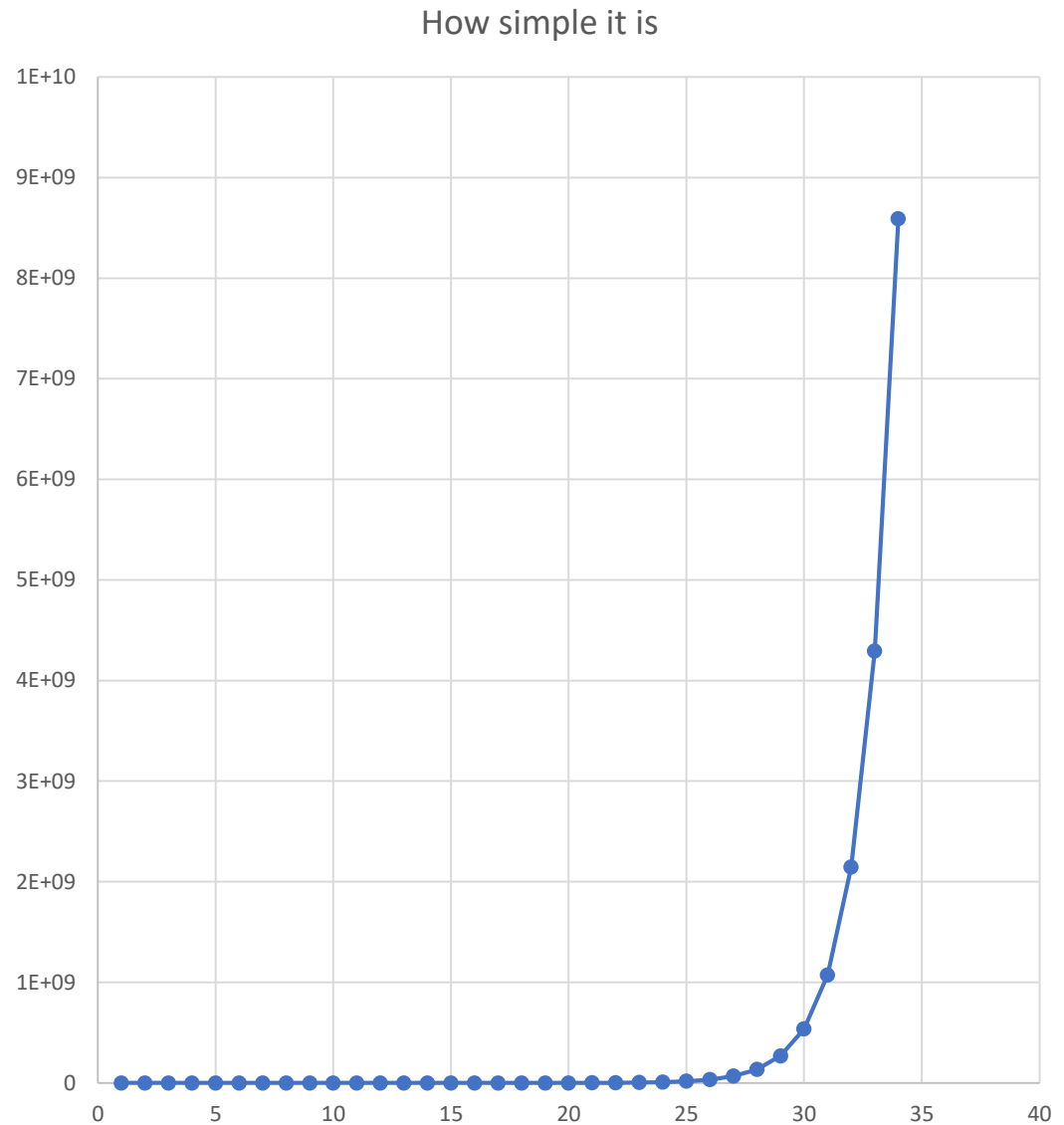
Reflection, heat content  
Melting, sea level rise  
Biodiversity  
...  
....  
Banking



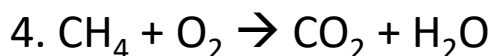
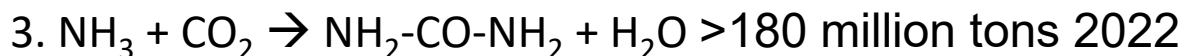
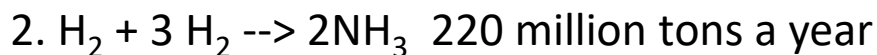
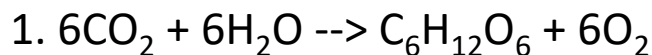


# Science made it possible

- 34 generations to make
- our population
- $34 \times 25 = 850$  years



# Reactions that changed the world



6. Polymerase chain reaction

7. Electrochemistry



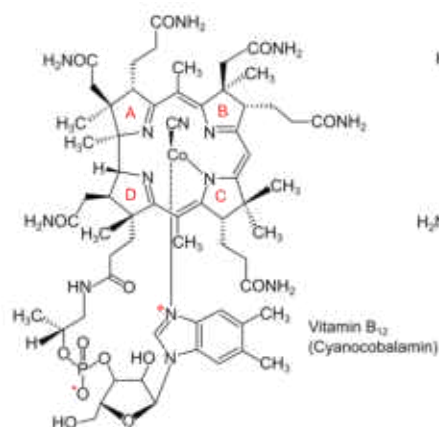


# Molecules that changed the world

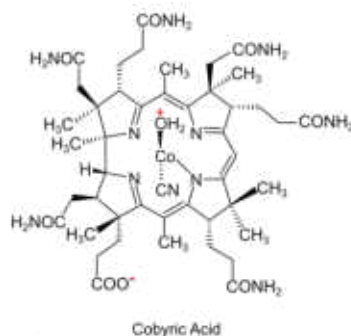
Aspirin, urea, morphine, strychnine, penicillin, vitamin B12, Taxol, and quinine

Molecules that destroyed the world

CFCs, DDT, Agent orange - 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), endosulfan



Vitamin B<sub>12</sub>  
(Cyanocobalamin)

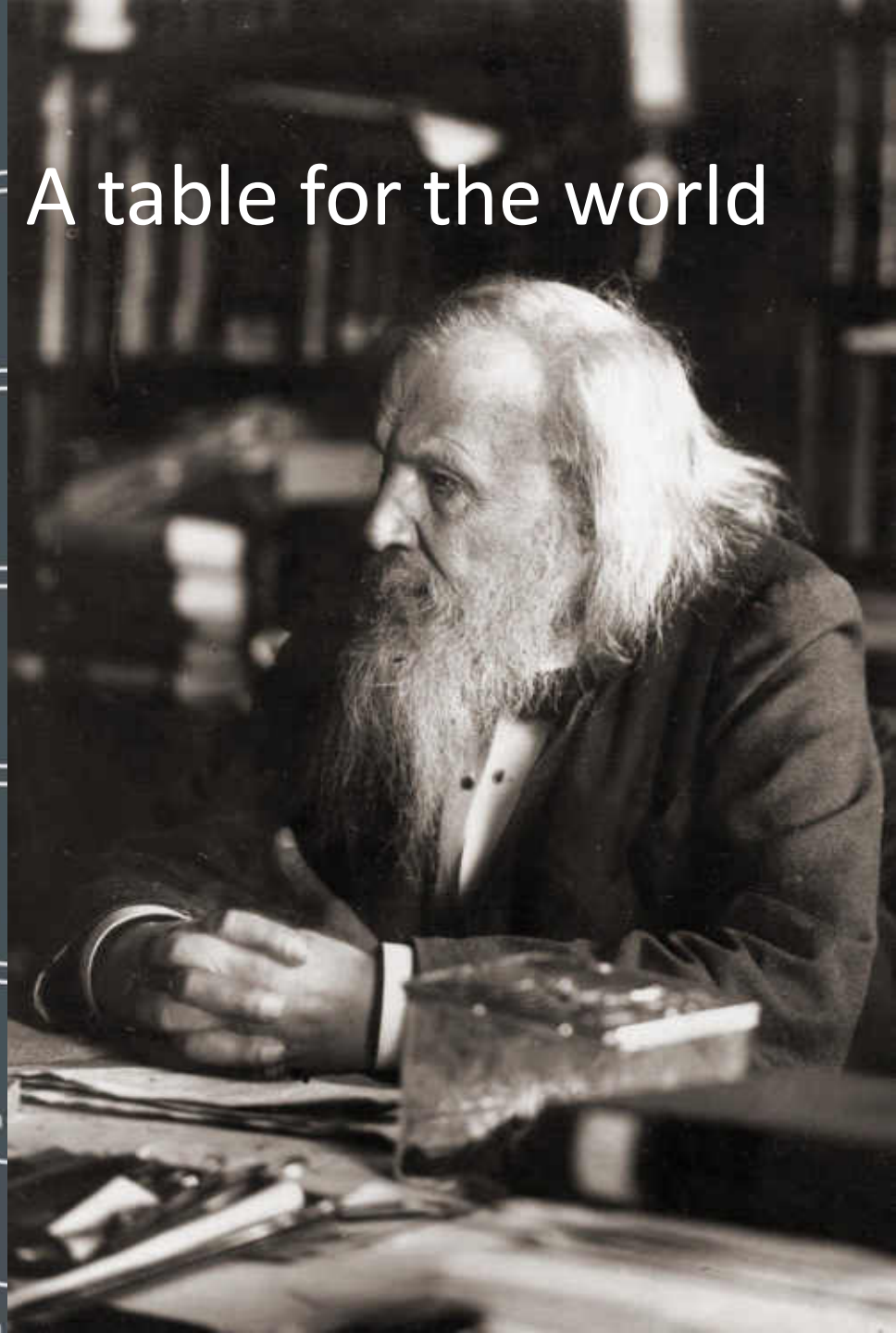


Cobyrinic Acid



5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999
13 <b>Al</b> Aluminium 26.9815385	14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.973761998	16 <b>S</b> Sulfur 32.06
30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.630	33 <b>As</b> Arsenic 74.921595
48 <b>Cd</b> Cadmium 112.414	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760
80 <b>Hg</b> Mercury 200.592	81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98040
112 <b>Cn</b> Copernicium (285)	113 <b>Nh</b> Nihonium (286)	114 <b>Fl</b> Flerovium (289)	115 <b>Mc</b> Moscovium (289)
67 <b>Ho</b> Holmium 164.93033	68 <b>Er</b> Erbium 167.259	69 <b>Tm</b> Thulium 168.934	70 <b>Yb</b> Ytterbium 173.054

A table for the world



# Molecules – Diseases and their cure

Reprinted from *Science*, November 23, 1949, Vol. 110, No. 2865, pages 545-548.

## Sickle Cell Anemia, a Molecular Disease<sup>1</sup>

Linus Pauling, Harvey A. Itano,\* S. J. Singer,\* and Ibert C. Wells\*

Gates and Crellin Laboratories of Chemistry,  
California Institute of Technology, Pasadena, California\*

**T**HE ERYTHROCYTES of certain individuals possess the capacity to undergo reversible changes in shape in response to changes in the partial pressure of oxygen. When the oxygen pressure is lowered, these cells change their forms from the normal biconcave disk to crescent, holly-leaf, and other forms. This process is known as sickling. About 8 percent of American Negroes possess this characteristic; usually they exhibit no pathological consequences attributable to it. These people are said to have sickle-cell trait. However, about 1 in 40 (4) of these individuals whose cells are capable of sickling suffer from a severe chronic anemia resulting from excessive destruction of their erythrocytes; the term sickle cell anemia is applied to their condition.

The main observable difference between the erythrocytes of sickle cell trait and sickle cell anemia has been that a considerably greater reduction in the partial pressure of oxygen is required for a major fraction of the trait cells to sickle than for the anemia cells (12). Tests *in vivo* have demonstrated that between 30 and 60 percent of the erythrocytes in the venous circulation of sickle cell anemia individuals, but less than 1 percent of those in the venous circulation of sickle-cell individuals, are normally sickled. Experiments *in vitro* indicate that under sufficiently low oxygen pressure, however, all the cells of both types assume the sickled form.

The evidence available at the time that our investigation was begun indicated that the process of sickling might be intimately associated with the state and the nature of the hemoglobin within the erythrocyte. Sickle cell erythrocytes in which the hemoglobin is combined with oxygen or carbon monoxide have the biconcave disk contour and are indistinguishable in

that form from normal erythrocytes. In this condition they are termed promesenchytes. The hemoglobin appears to be uniformly distributed and randomly oriented within normal cells and promesenchytes, and no birefringence is observed. Both types of cells are very flexible. If the oxygen or carbon monoxide is removed, however, transforming the hemoglobin to the uncombined state, the promesenchytes undergo sickling. The hemoglobin within the sickled cells appears to aggregate into one or more foci, and the cell membrane collapses. The cells become birefringent (17) and quite rigid. The addition of oxygen or carbon monoxide to these cells reverses these phenomena. Thus the physical effects just described depend on the state of combination of the hemoglobin, and only secondarily, if at all, on the cell membrane. This conclusion is supported by the observation that sickled cells when lysed with water produce discoidal, rather than sickle-shaped, ghosts (10).

It was decided, therefore, to examine the physical and chemical properties of the hemoglobins of individuals with sickle-cell anemia and sickle cell trait, and to compare them with the hemoglobin of normal individuals to determine whether any significant differences might be observed.

### EXPERIMENTAL METHODS

The experimental work reported in this paper deals largely with an electrophoretic study of these hemoglobins. In the first phase of the investigation, which concerned the comparison of normal and sickle cell anemia hemoglobins, three types of experiments were performed: 1) with carbonmonoxyhemoglobins; 2) with uncombined ferrihemoglobins in the presence of dithionite ion, to prevent oxidation to methemoglobin; and 3) with carbonmonoxyhemoglobins in the presence of dithionite ion. The experiments of type 3 were performed and compared with those of type 1 in order to ascertain whether the dithionite ion itself causes any specific electrophoretic effect.

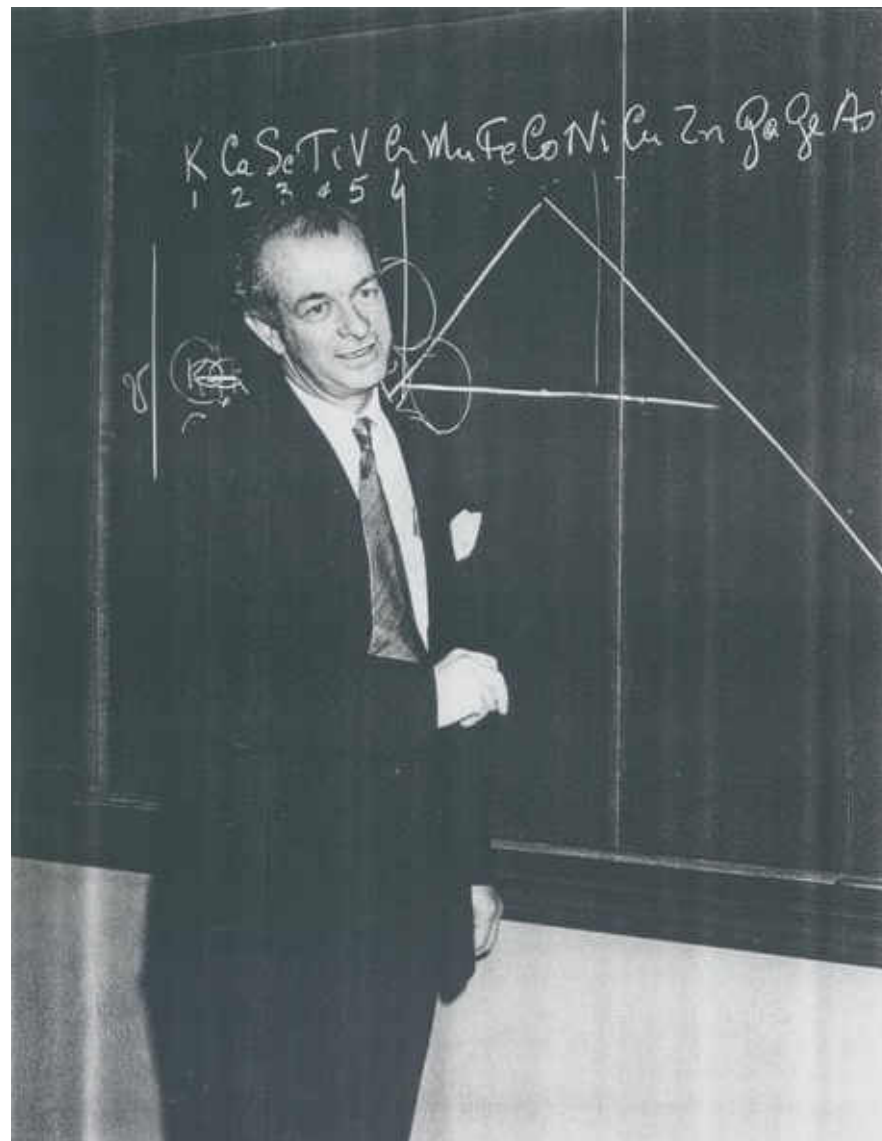
Samples of blood were obtained from sickle cell anemia individuals who had not been transfused within three months prior to the time of sampling. Strain-free concentrated solutions of human adult hemoglobin were prepared by the method used by Drabkin (18). These solutions were diluted just before use with the

<sup>1</sup>This research was carried out with the aid of a grant from the United States Public Health Service. The authors are grateful to Professor Ray D. Olsen, of the Henry Draper of this Institute, for his helpful suggestions. We are indebted to Dr. Edward B. Brann, of Pasadena, Dr. Yeakle Whaley, of Los Angeles, and Dr. G. K. Barth, of the Tulane University School of Medicine, New Orleans, for their aid in obtaining the blood used in these experiments.

\*U. S. Public Health Service postdoctoral fellow at the National Institute of Health.

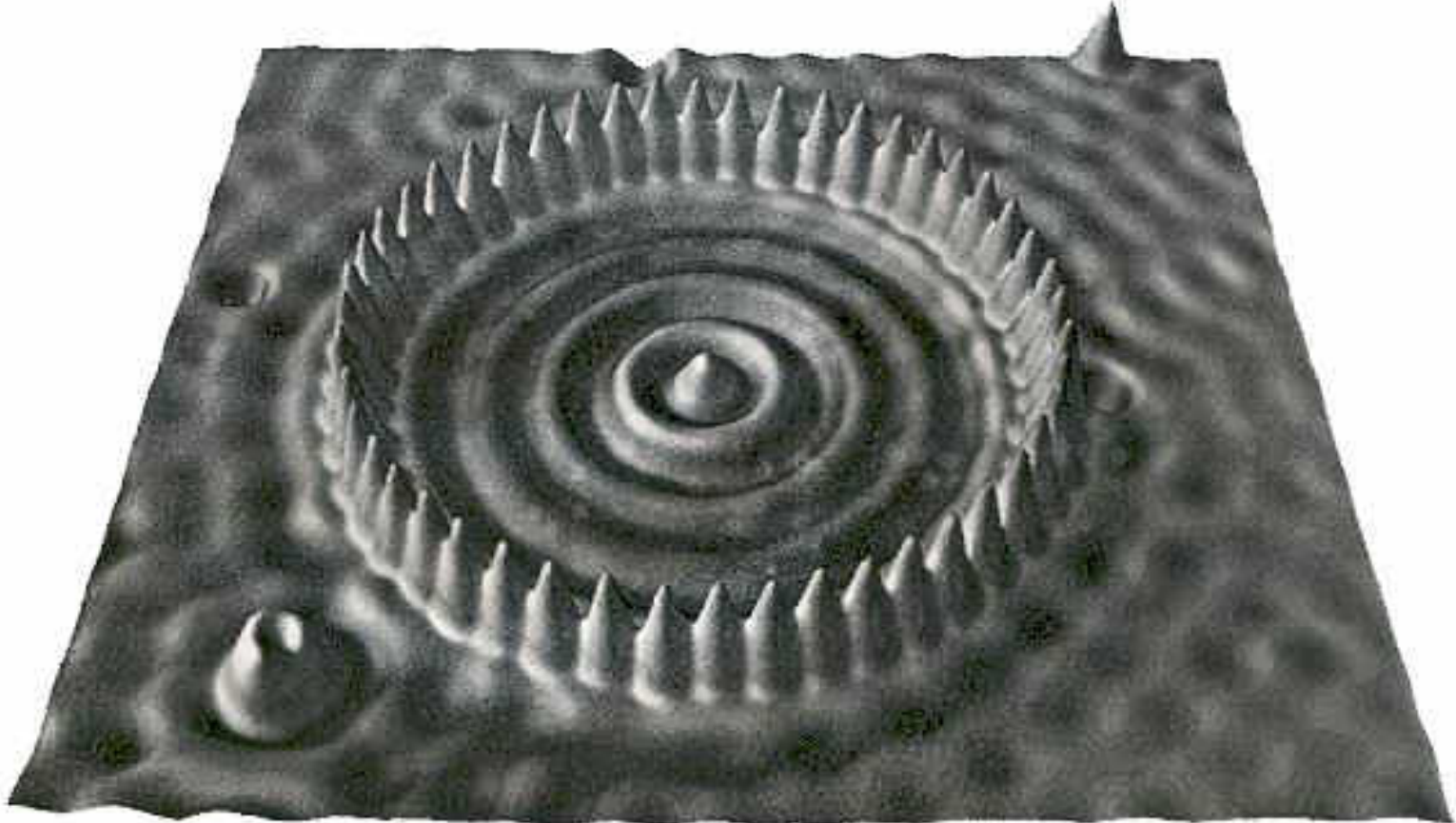
\*Postdoctoral fellow of the Division of Medical Sciences of the National Research Council.

<sup>1</sup>Contribution No. 1228.





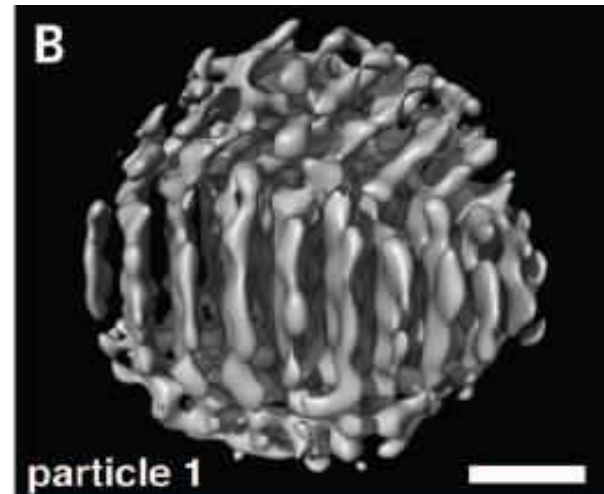
# Instrumentation



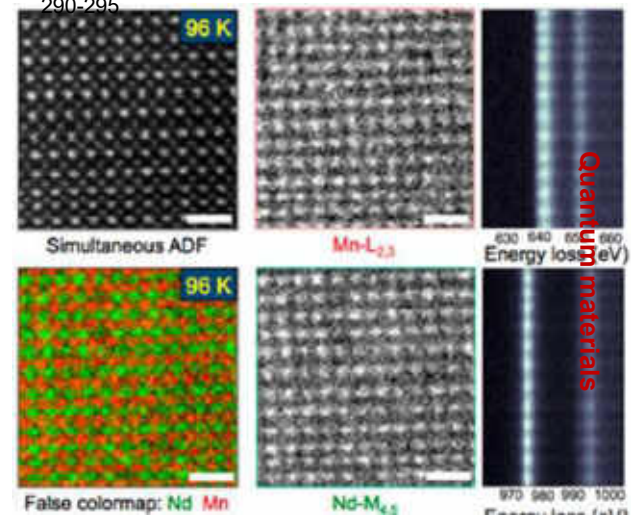
STM image of a “quantum corral” (courtesy IBM Research Division).

D. W. Eigler, et. Al. Science, 262(5131), 218-220.

# Seeing atoms, molecules and assemblies



3D Structure of Individual Nanocrystals in Solution by Electron Microscopy. Park, J. et al., *Science* **2015**, 349, 290-295.



Baek, D. J. et al., *Microsc. Microanal.* **2018**, 24, 454–455  
Nature and evolution of incommensurate charge order in manganites visualized with cryogenic scanning transmission electron microscopy. Baggari, I. E. et al., *Proc. Natl. Acad. Sci.* **2018**, 115, 1445–1450.

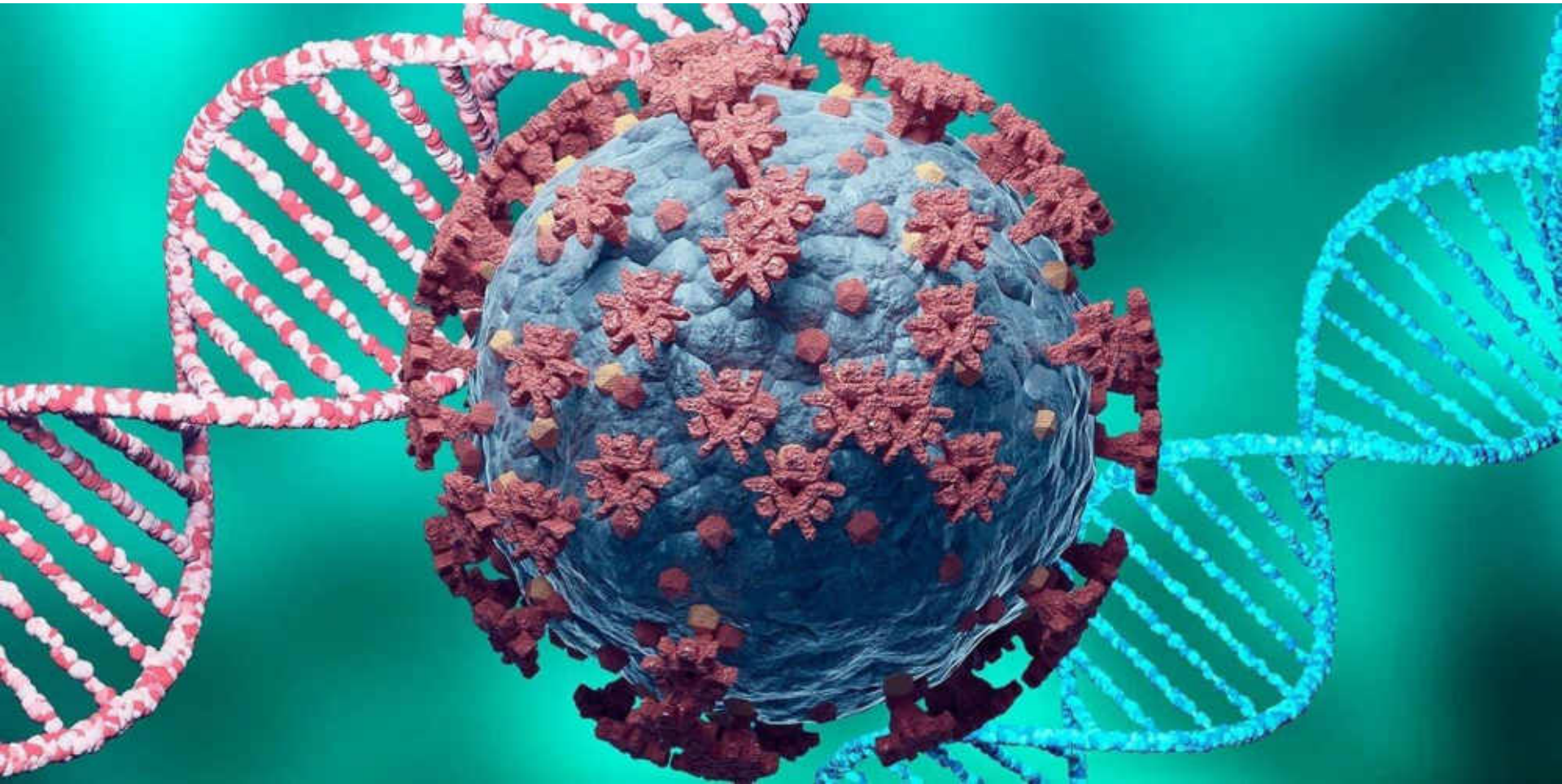
<https://www.....>



From <https://www.simplilearn.com/what-is-internet-article>



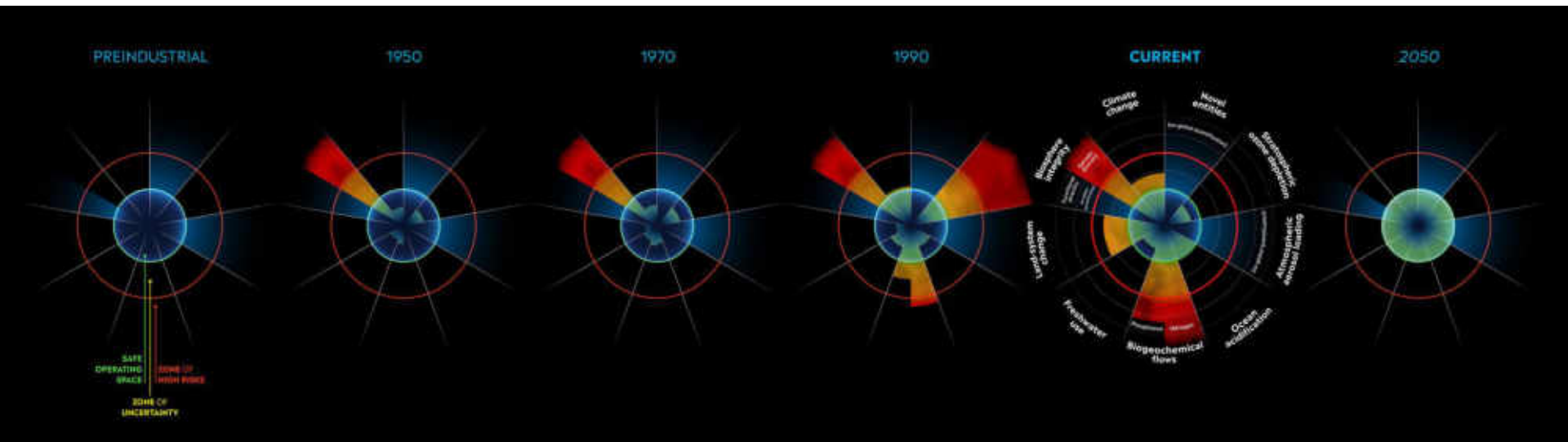
Nature, engineering, life....



From WHO

# Our restriction – confined space

## Planetary boundaries



<https://globalia.org/planetary-boundaries>



We developed environmentally friendly water positive nanoscale materials for affordable, sustainable and rapid removal of arsenic from drinking water.

There are over 1700 community installations across the country, serving 1.3 million people with arsenic and iron-free water every day.



# Biopolymer-reinforced synthetic granular nanocomposites for affordable point-of-use water purification

Mohan Udhaya Sankar<sup>1</sup>, Sahaja Aigal<sup>1</sup>, Shihabudheen M. Maliyekkal<sup>1</sup>, Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep<sup>2</sup>

<sup>1</sup>Unit of Nanoscience and Thematic Unit of Ex

Edited by Eric Hoek, University of California,

Creation of affordable materials for cons water is one of the most promising way drinking water for all. Combining the composites to scavenge toxic species other contaminants along with the ab affordable, all-inclusive drinking water without electricity. The critical proble synthesis of stable materials that can uously in the presence of complex s drinking water that deposit and caus surfaces. Here we show that such can be synthesized in a simple and effective out the use of electrical power. The na sand-like properties, such as higher shea forms. These materials have been used water purifier to deliver clean drinking ily. The ability to prepare nanostructu ambient temperature has wide releva water purification.

hybrid | green | appropriate technology | frugal science | developing world



Madras, Chennai 600 036, India

(received for review November 21, 2012)

available; and (c) continued retention matrix is difficult. ate a unique family of nanocrystalline n granular composite materials pre- ature through an aqueous route. The mposition is attributed to abundant -O on chitosan, which help in the crys- oxide and also ensure strong covalent : surface to the matrix. X-ray photo- ) confirms that the composition is rich ps. Using hyperspectral imaging, the aching in the water was confirmed. to reactivate the silver nanoparticle ial antimicrobial activity in drinking osites have been developed that can its in water. We demonstrate an af- device based on such composites de- und undergoing field trials in India, as :spread eradication of the waterborne

RESULTS AND DISCUSSION

M. Udhaya Sankar, et. al. *Proc. Natl. Acad. Sci.*, 110 (2013) 8459-8464.



# Where can we invest our time and effort?

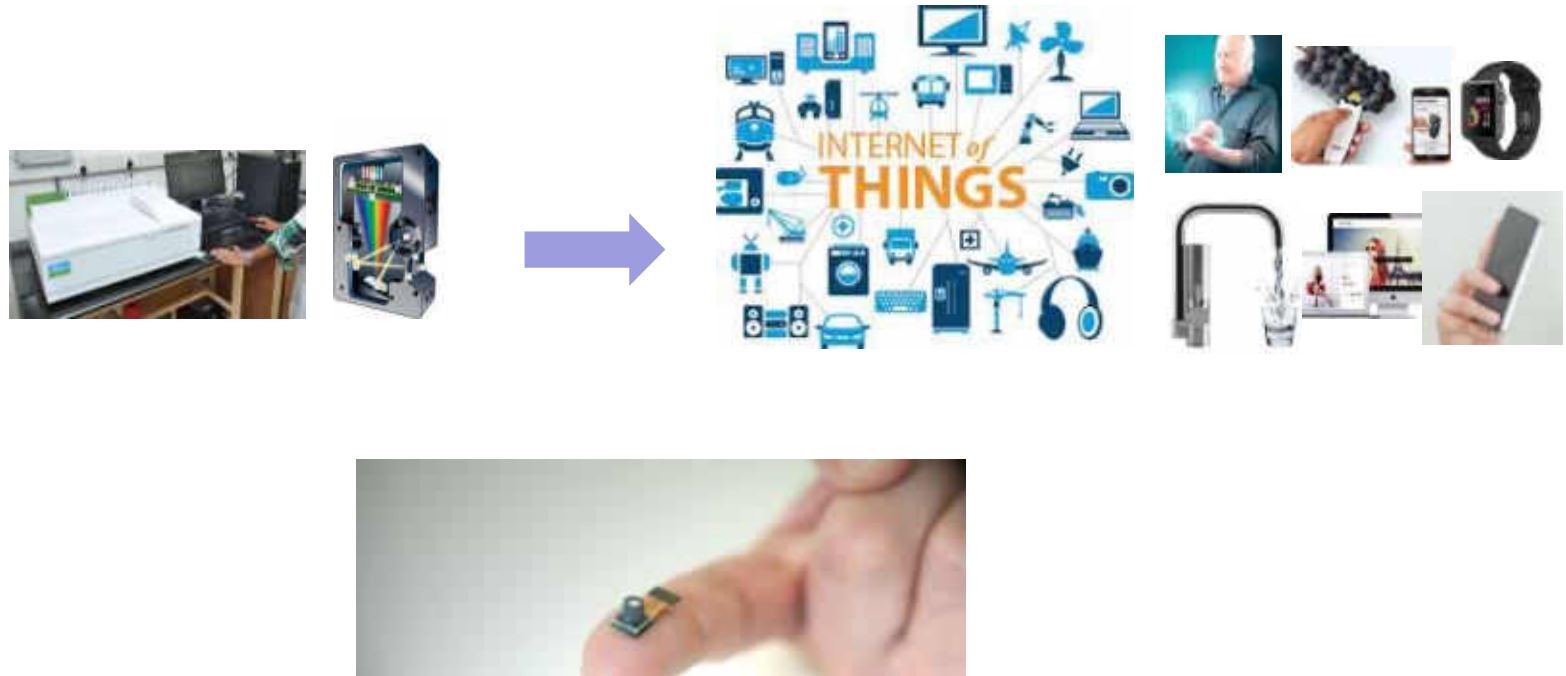
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# Sensors and new opportunities

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Water quality measurement – In the pipeline



# Indian Institute of Technology Madras



Bhaskar Ramamurthi/V. Kamakoti

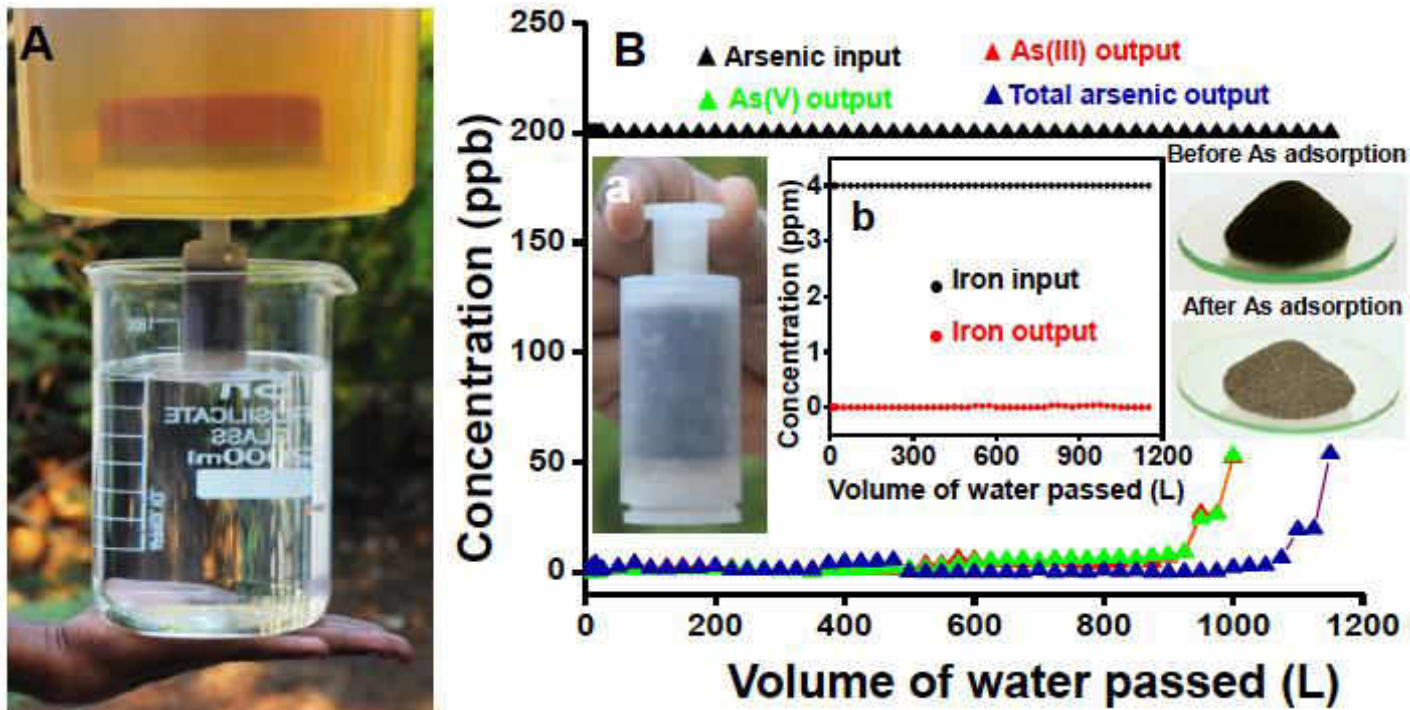


Thank you all

[pradeep@iitm.ac.in](mailto:pradeep@iitm.ac.in)

<https://pradeepresearch.org/>

# Range of materials, their affordability and safety



Safety of spent media, TCLP

A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

# Clean water for everyone

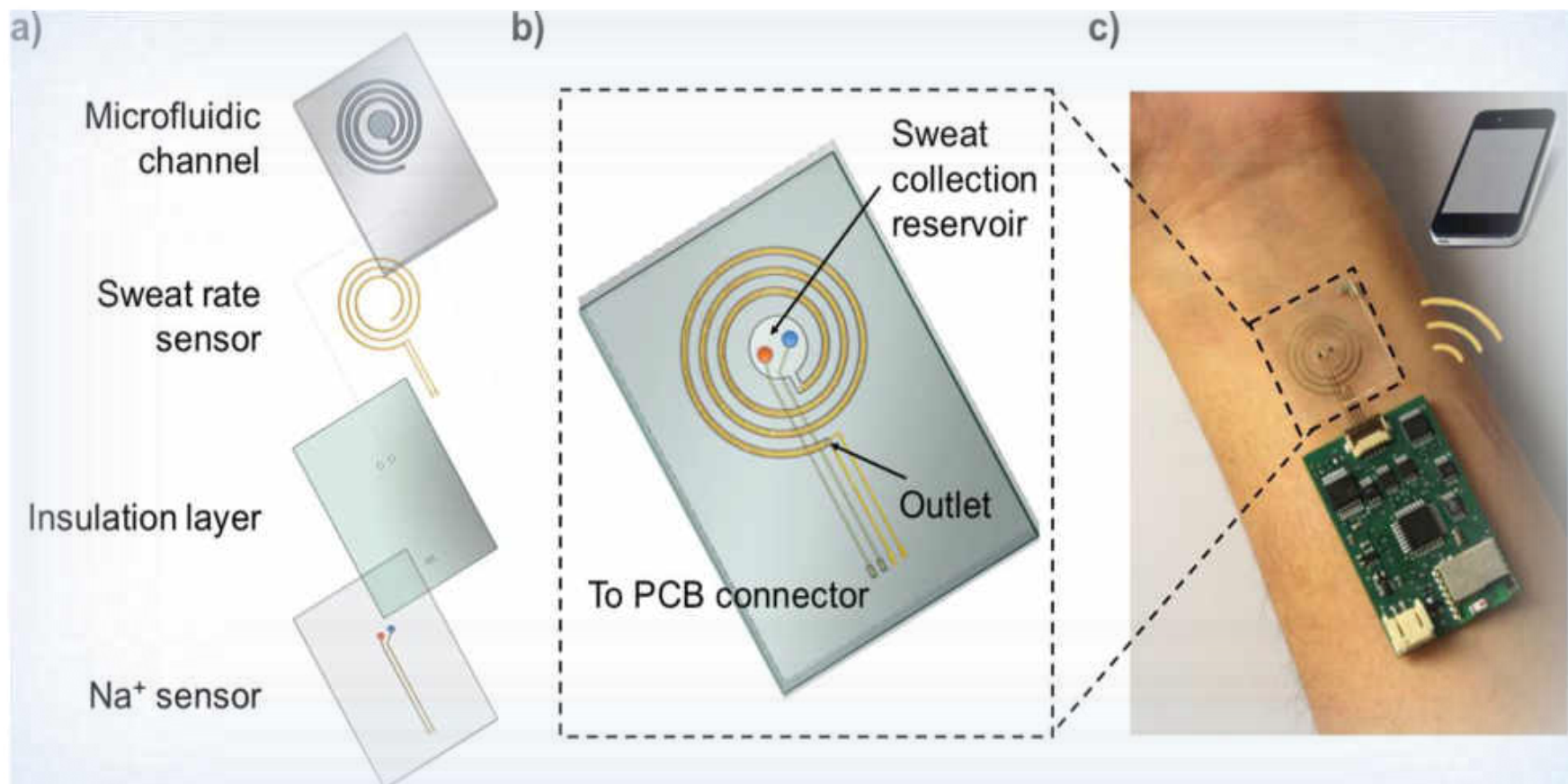
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ACS Sustainable Chemistry & Engineering Editorial,  
December 2016



# Health



# Implementation - From 25 KLD to 1 MLD



**Large water supply schemes**  
**Capacity: above 1 MLD**

**5 schemes in use across India**



**Retrofitted Water Purification Plant**  
**Capacity: 0.1-1 MLD**

**Over 180 units in use across India**

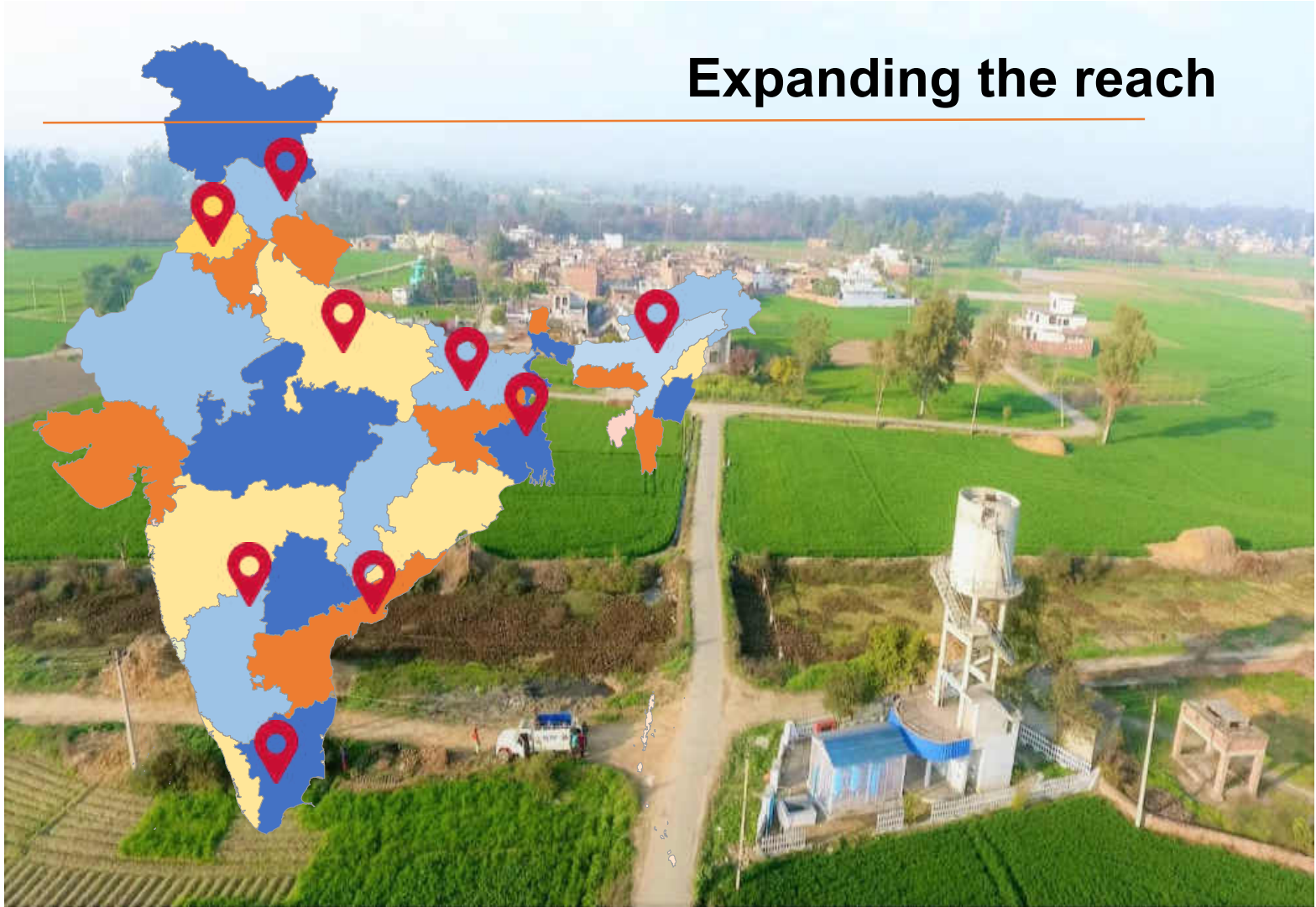


# Across the country

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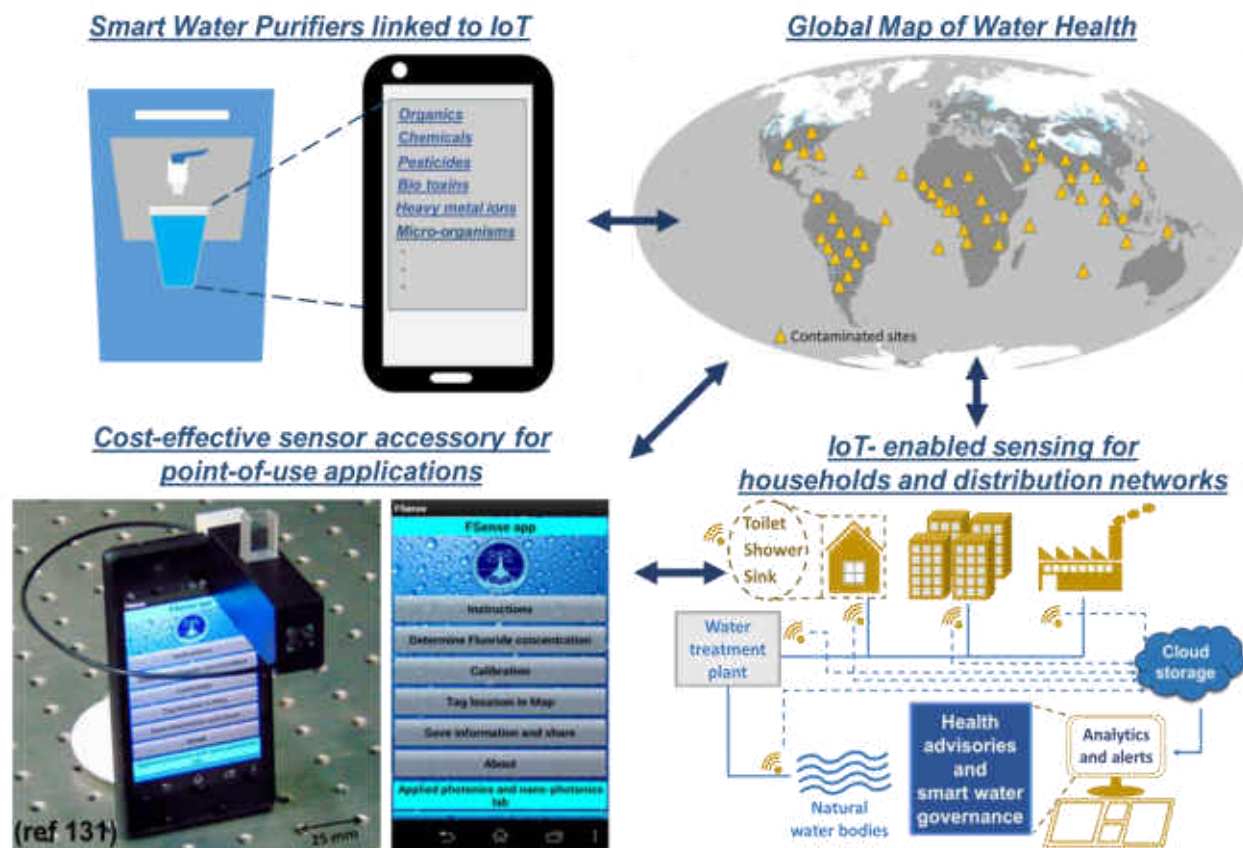


## Expanding the reach



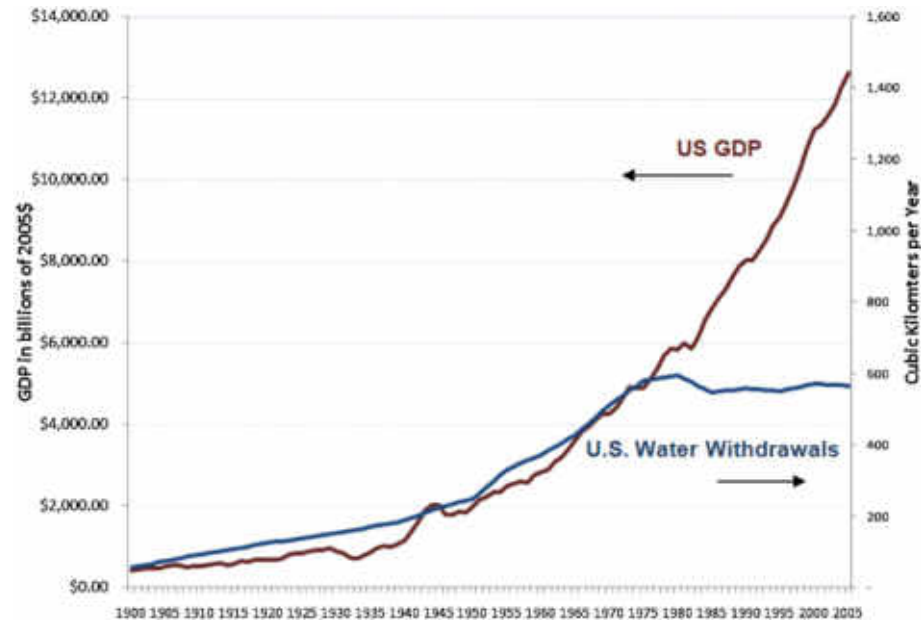


# Smart water purifiers and big data



Ankit Nagar and Thalappil Pradeep. *ACS Nano* (perspective), 2020.

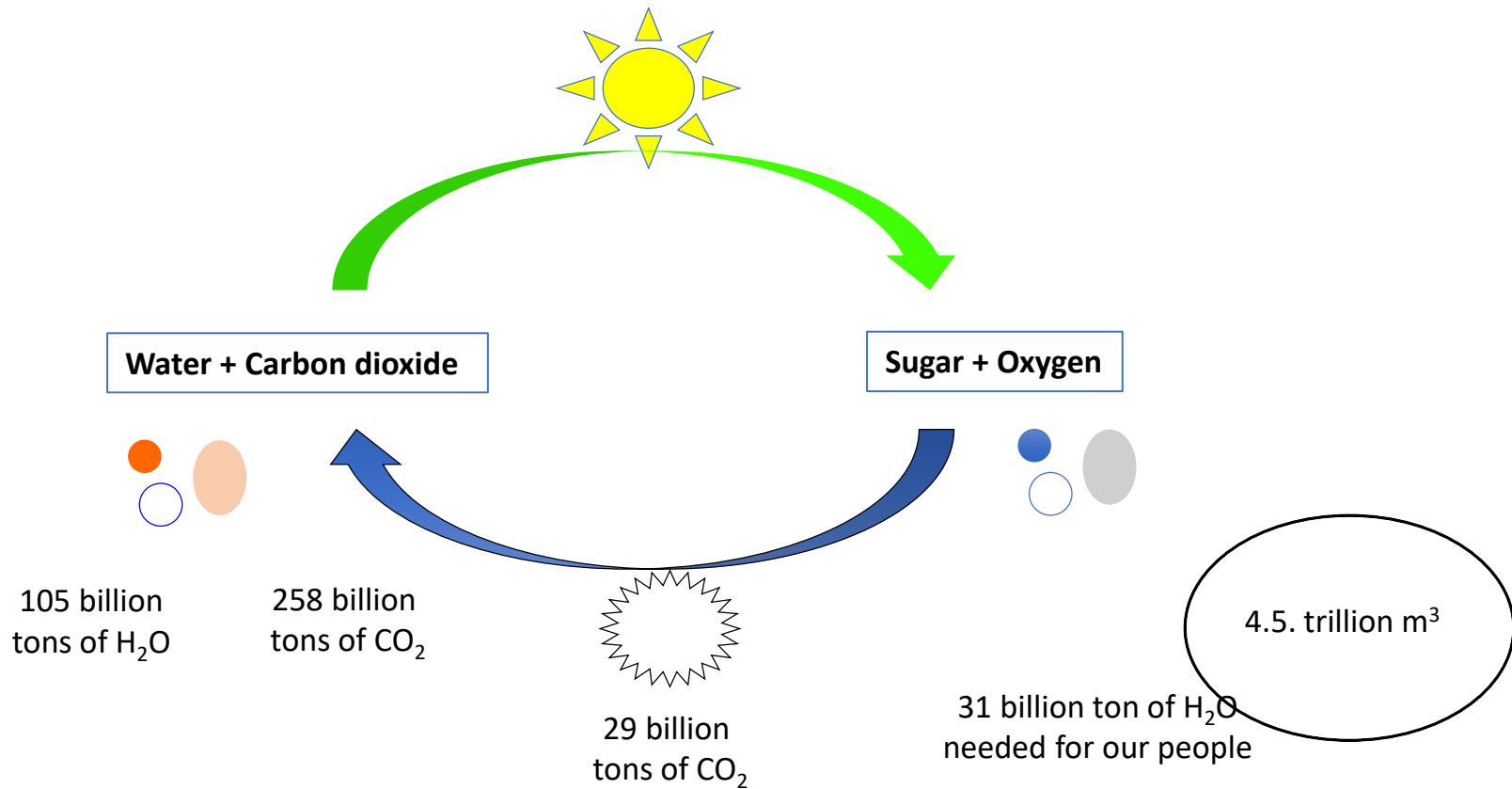
# Water and GDP



US gross domestic product (GDP) in 2005 dollars from 1900 to 2005 (left axis) plotted with total water withdrawals for all purposes in cubic kilometers per year (right axis). Data on GDP come from the US Bureau of Economic Analysis; data on water use comes from the US Geological Survey.

Peter H. Gleick and Meena Palaniappan, Peak water limits to freshwater withdrawal and use, PNAS, 2010, 107, 11155–11162

## We opened the cycle





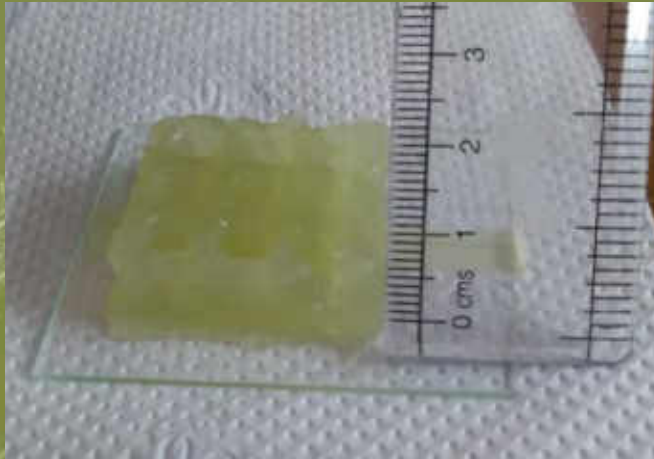
Biological complexity is built with just a few elements





# Food

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Author's laboratory