Polymers for Future Electronics

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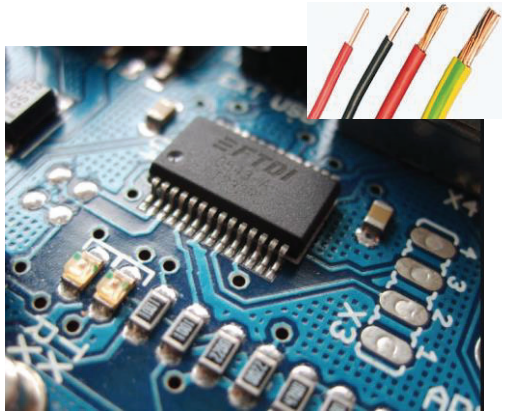
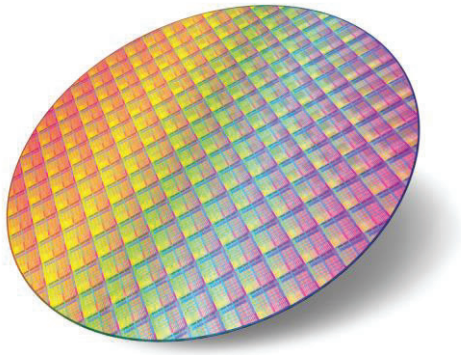
Materials for Current Electronics and Displays

https://www.notebookcheck.net/



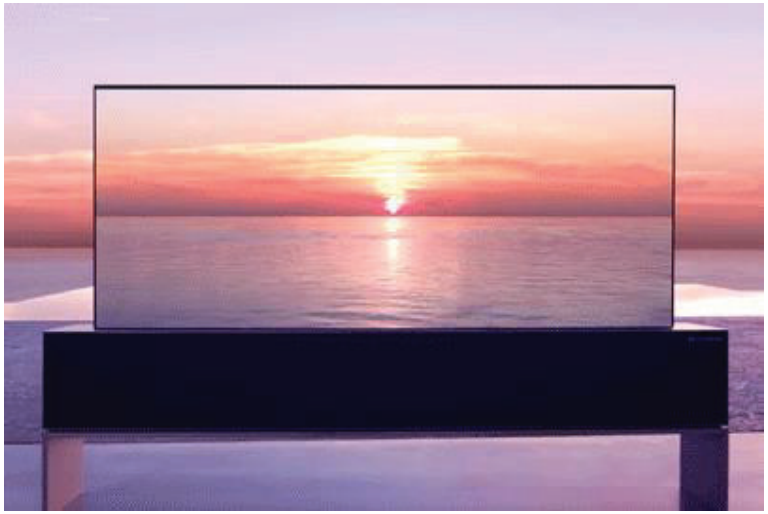
https://en.wikipedia.org/wiki/Electronics



https://siliconsemiconductor.net/

Conductor (e.g., metals, metal oxides)
Semiconductor (e.g., silicon)
Insulator (e.g., metal oxide, **polymers**)
Circuit board (e.g., **polymers**; PCB)
Packaging (e.g., **polymers**)
Photoresist (e.g., **polymers**)
Display (e.g., glass, LCD, OLED)
Cases (e.g., **polymers**)

Materials for Current Electronics and Displays



https://aboutsoft.top/53-lg-rolled-up-tv-will-be-available-this-year.html

https://news.samsung.com/us/galaxy-z-flip-unpacked2020-future-changes-shape/

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Contents: Polymers for Future Electronics

Part I. Human-friendly electronics

https://spectrum.ieee.org/biomedical/devices/

Part II: Green electronics

M. Irimia-Vladu, Chem. Soc. Rev., 2014

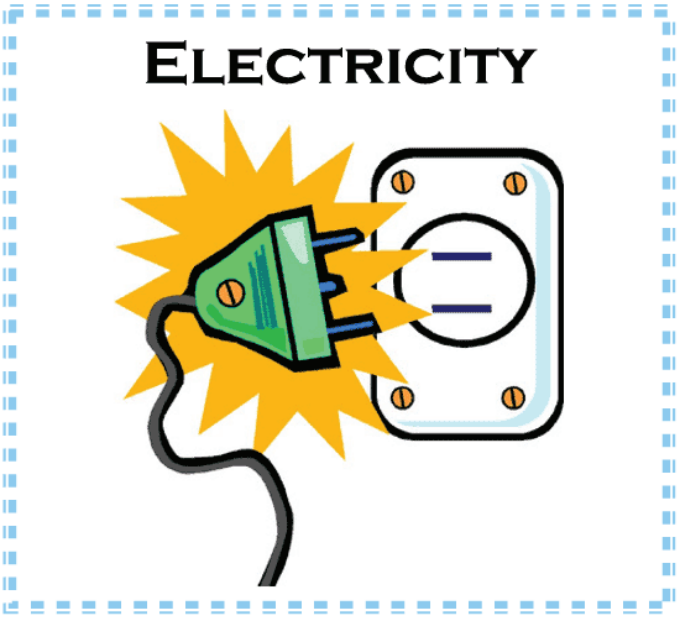
Conclusing remarks

Conducting Polymers

Plastic: light, flexible, etc.

www.captainpao.com

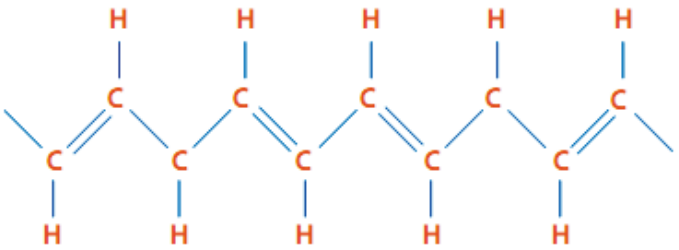
But, electrically conductive!



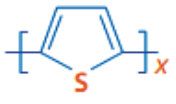
www.unpluggedliving.com

Beneficial for skin, textile, stretchable electronics

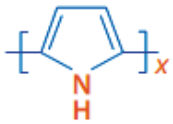
Conducting Polymers



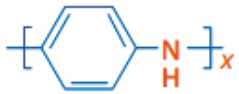
Trans-polyacetylene



Polythiophene

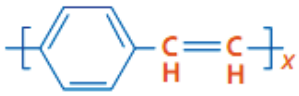


Polypyrrole

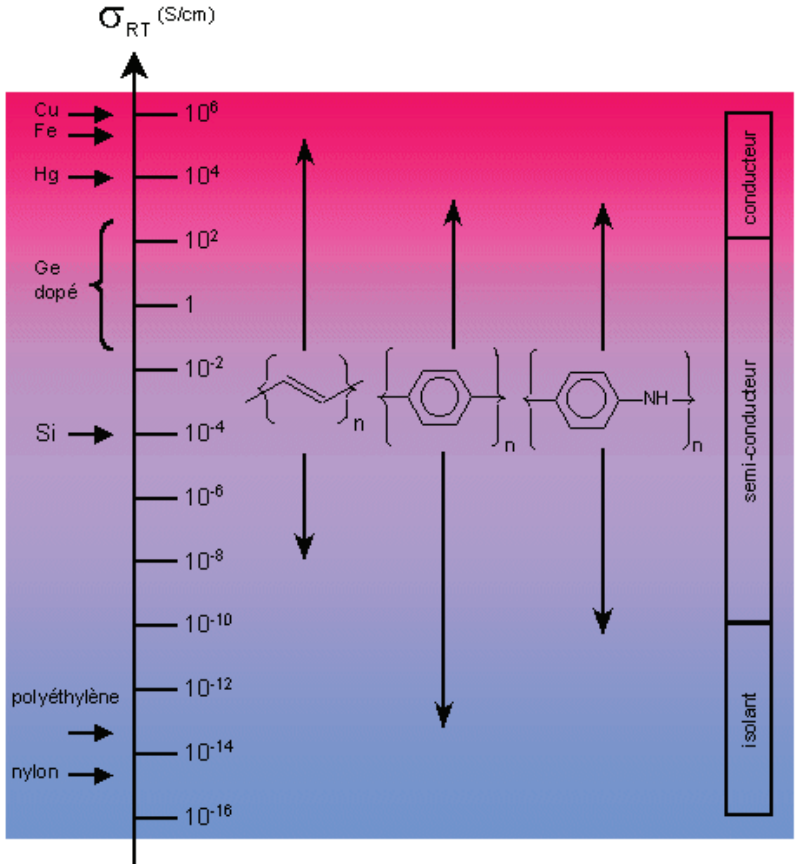


Polyaniline

Poly(*p*-phenylene)



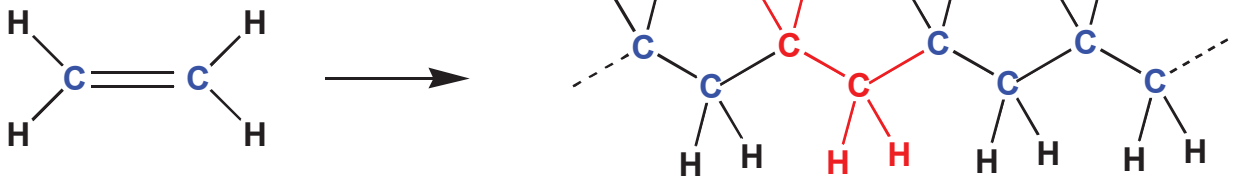
Poly(*p*-phenylenevinylene)



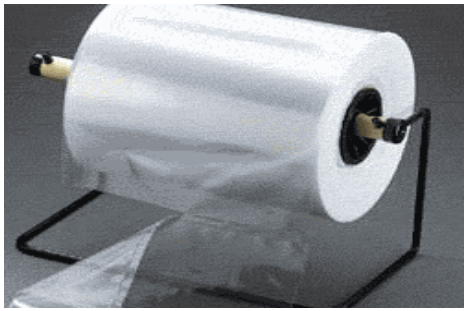
Decent electrical conductivity after doping
Mechanical flexibilty
Solution processibility

Why Electrically Conductive?

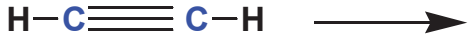
Traditional plastic: polyethylene



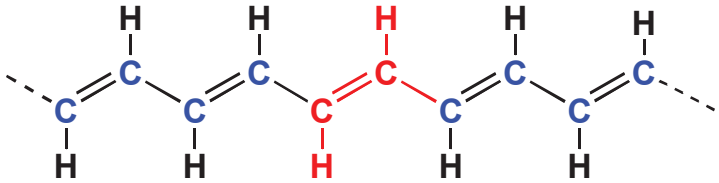
Ethylene



Conducting polymer: trans-polyacetylene



Acetylene



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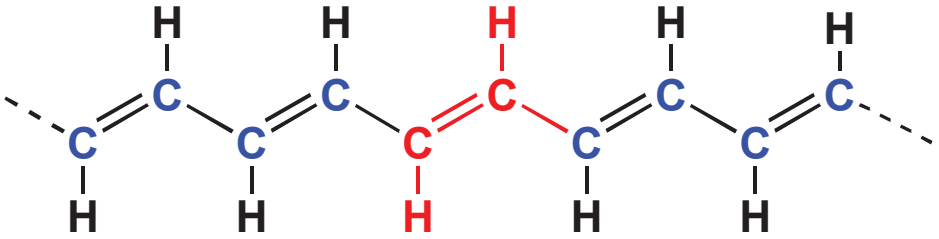
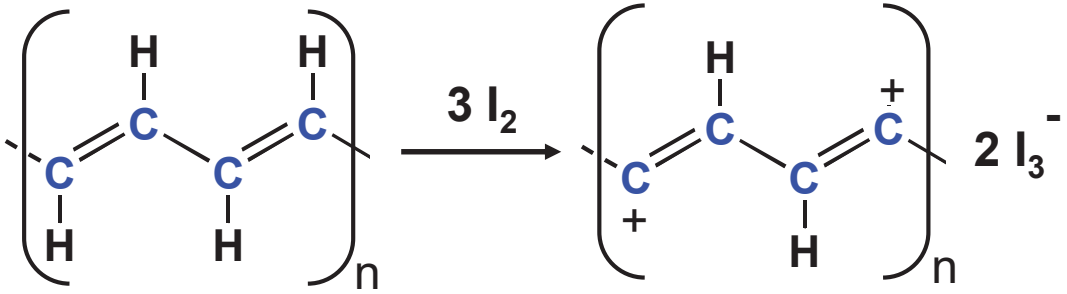
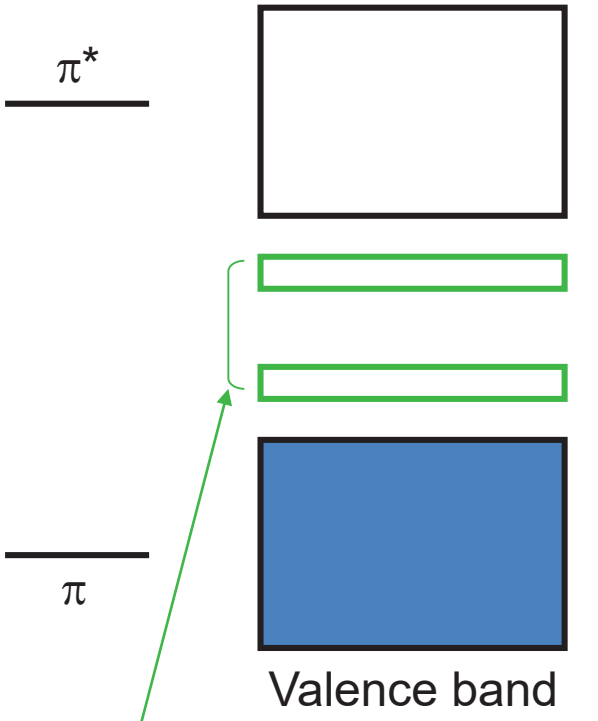


$CH_2=CH_2$ $\quad$ $-(CH=CH)-_n$

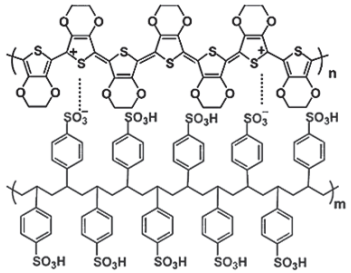
1. Conjugated π-system
- **Alternating single and multiple bonds**
- **Enabling band-like electronic structures**



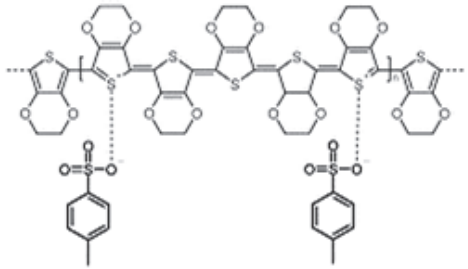
2. Doping (chemically or electrochemically)
- **Extra energy bands**
- **Charge carrier introduction**



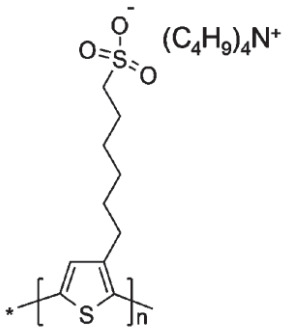
Organic Mixed Ionic-Electronic Conductors (OMIECs)



PEDOT:PSS

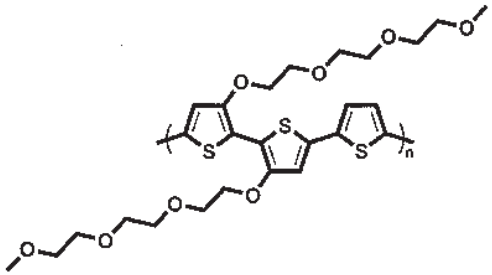


PEDOT:Tos



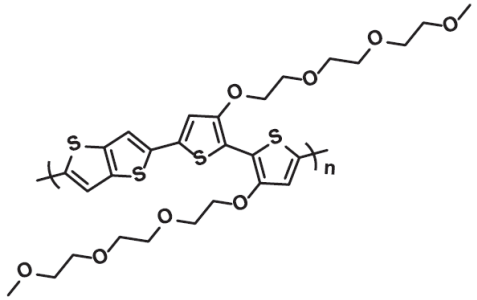
PTHS

Malliaras et al., Adv. Mater (2014)



P(g2T-T)

McCulloch et al., JACS (2016)

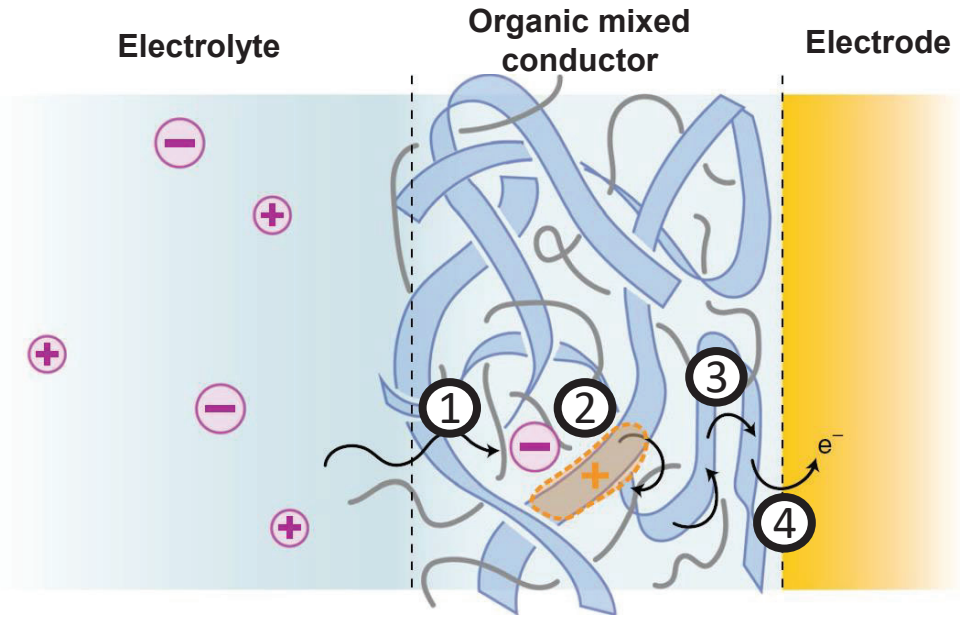


P(g2T-TT)

Rivnay et al., PNAS (2016)

Ionic and electronic conductivities

Organic Mixed Ionic-Electronic Conductors



Paulsen et al. *Nature Mater.* 19:13-26 (2020)

① **Dopant ion injection and migration**

② **Charge carrier (hole) stabilization by dopant ion**

③ **Charge carrier (hole) hopping**

④ **Charge transfer between active layer and electrode**

***All processes take place simultaneously.**

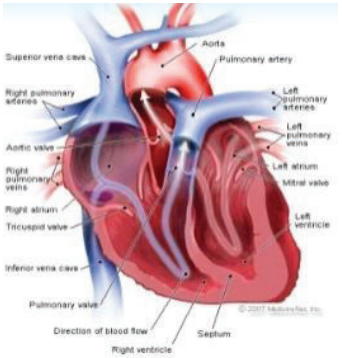
Electronic transport
+
Ionic transport

→ **Electric/electrochemical reaction with electrolytes** → **Suitable for *bioelectronics***

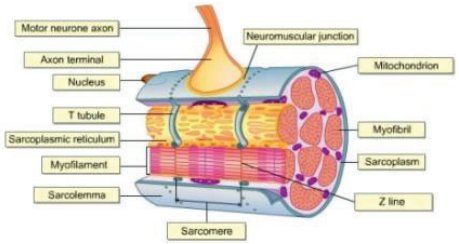
Organic mixed conductors can transport not only electrical but also ionic charge carriers, so they can be useful in *interfacing ion-based bioelectric signals*.

Organic Mixed Ionic-Electronic Conductors for Bioelectronics

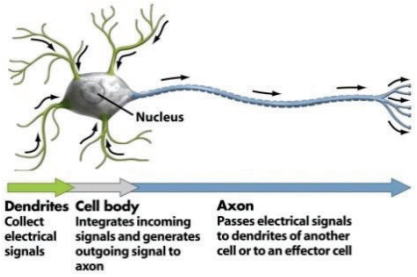
Bioelectricity



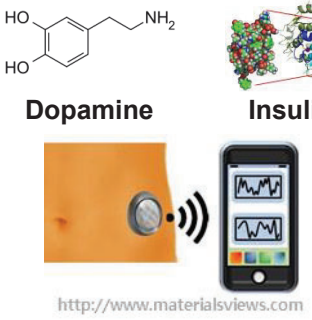
Heart



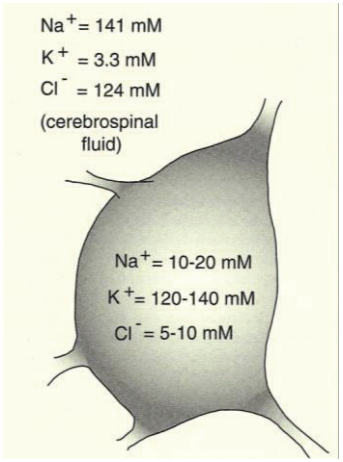
Muscle



Nerve



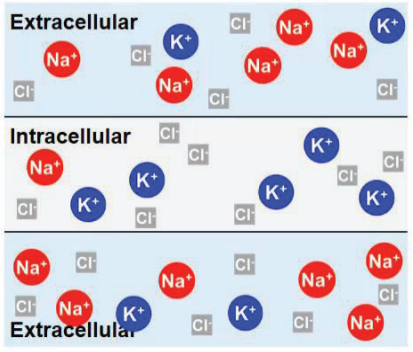
Endocrinal system

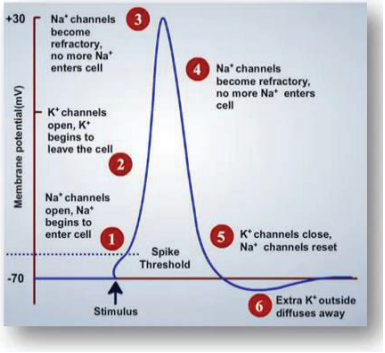


Nernst equation

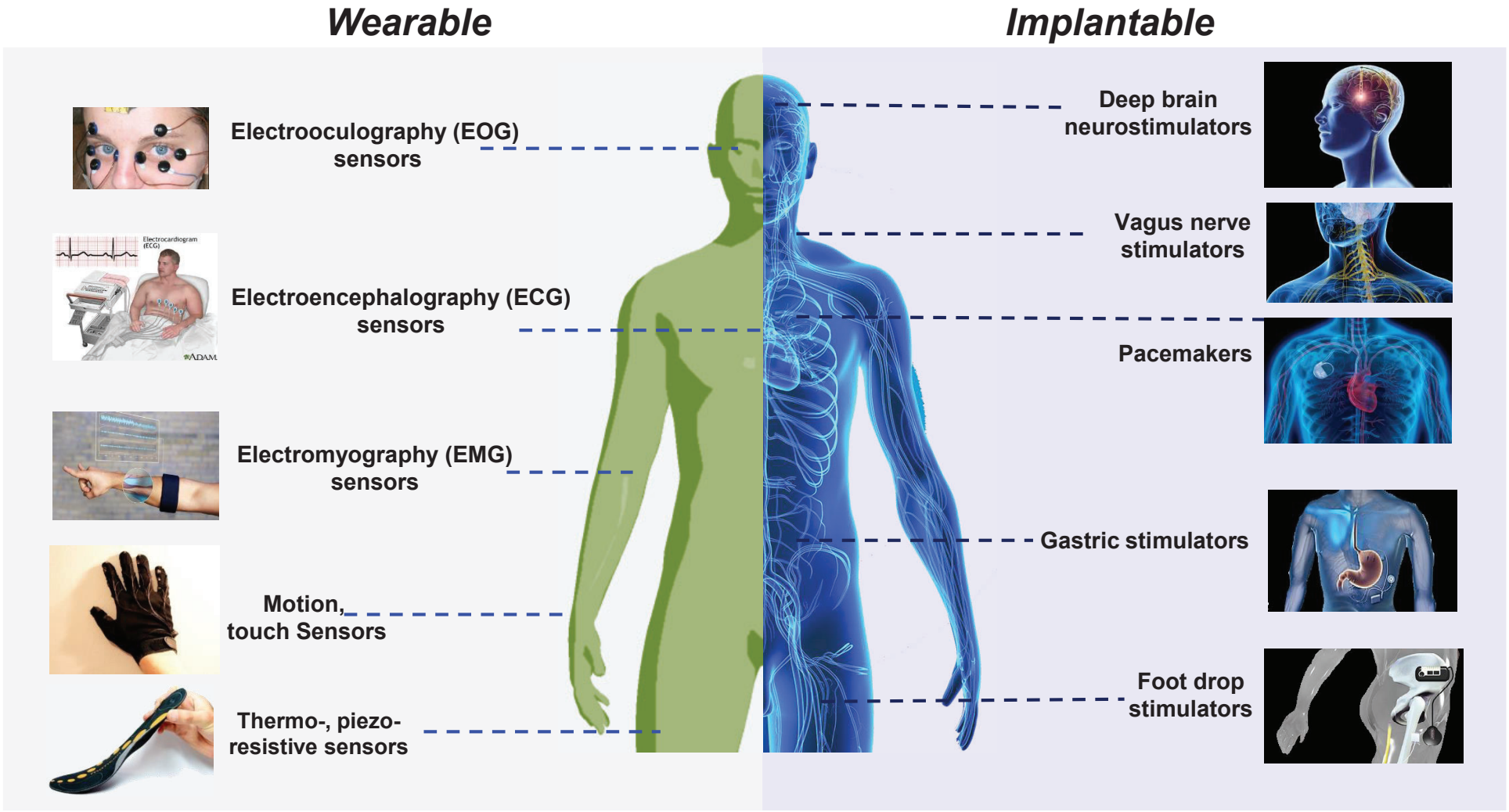
$$V = \frac{RT}{zF} \ln \frac{[K^+]_o}{[K^+]_i}$$

"Resting membrane potential"



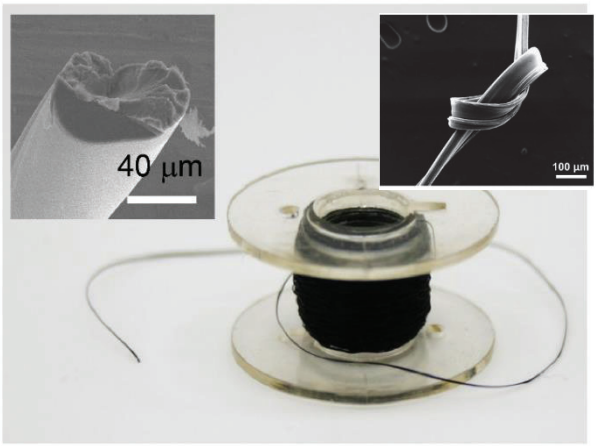


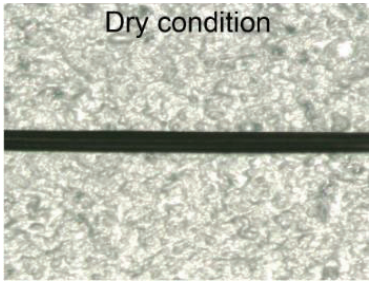
Organic Mixed Ionic-Electronic Conductors for Bioelectronics

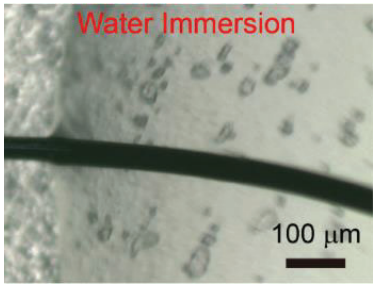


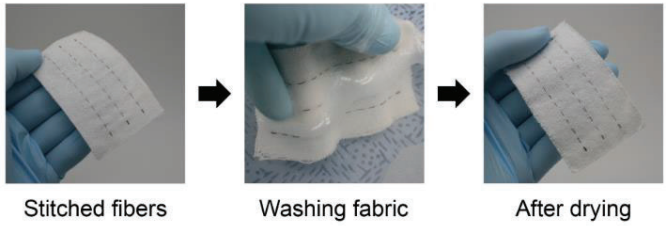
Many different types of bioelectronic devices have been developed for biological signal recording, information processing, and stimulation.

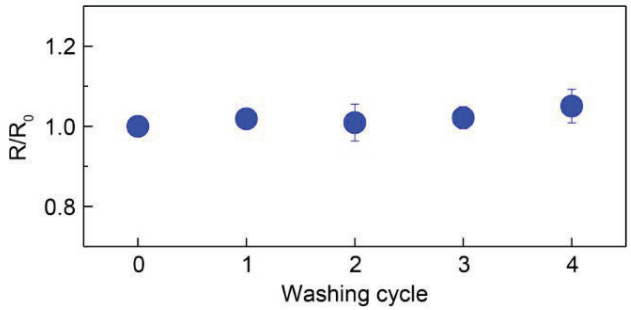
OMIEC Fibers for EMG and Sweat Sensing

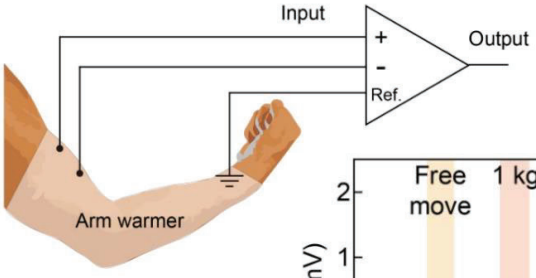


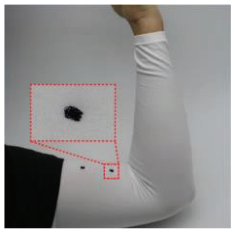


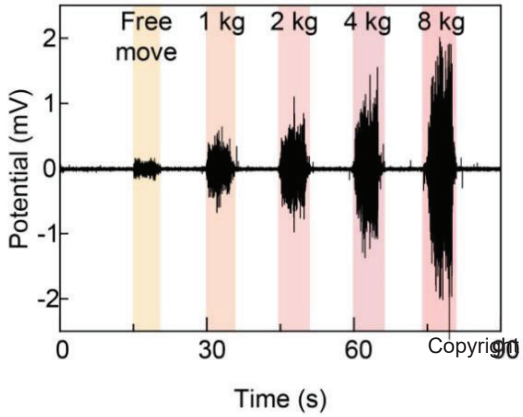


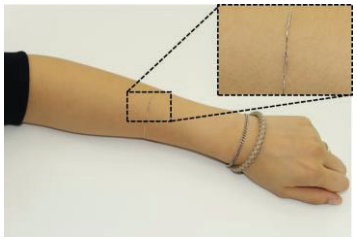


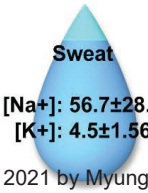


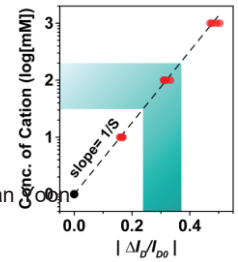


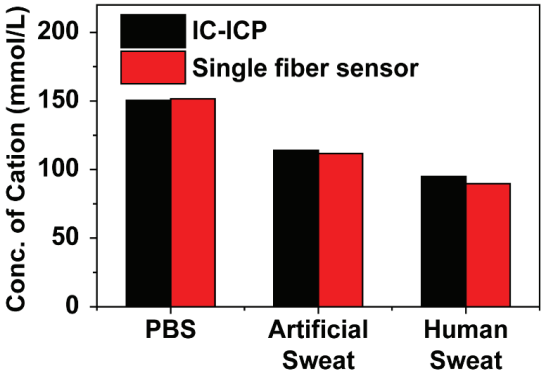












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https://spectrum.ieee.org/biomedical/devices/

Part II: Green electronics

M. Irimia-Vladu, Chem. Soc. Rev., 2014

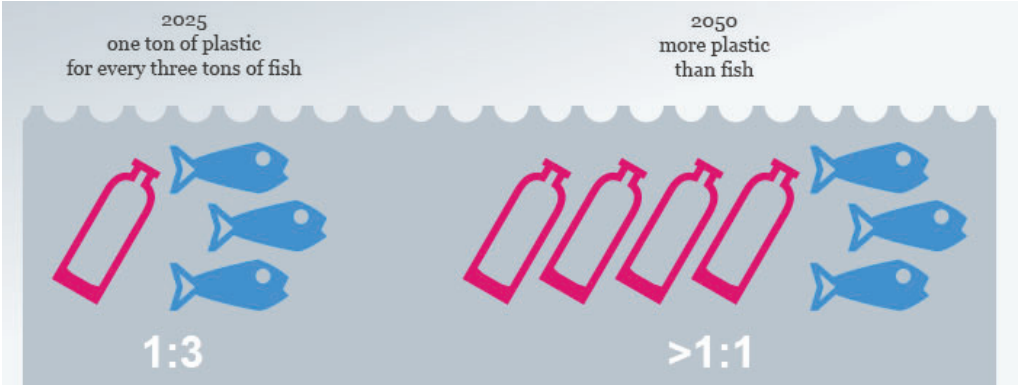
Conclusing remarks

Pollution By Petroleum-based Non-degradable Plastic

https://egyptindependent.com/ocean-plastic-predicted-to-triple-within-a-decade/

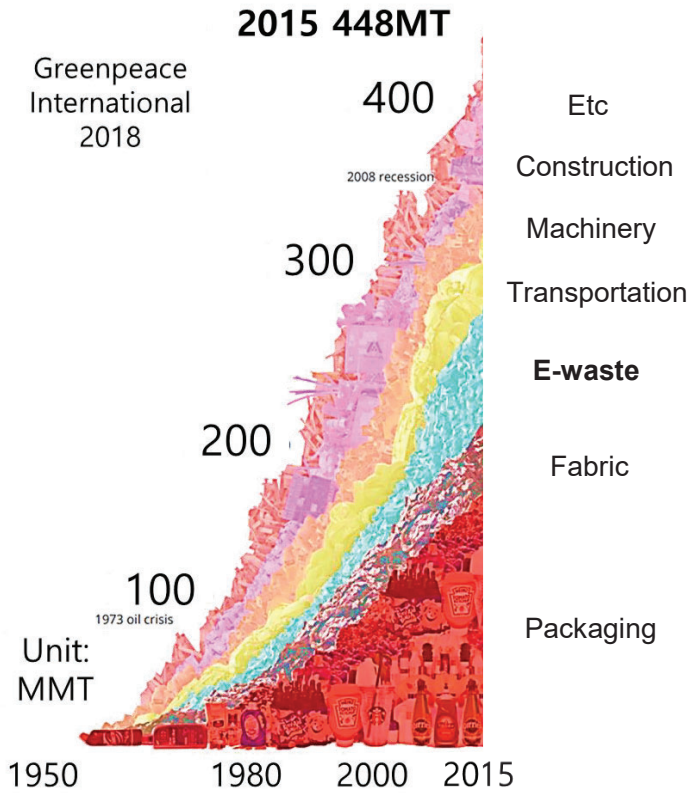
https://www.independent.co.uk/climate-change/

https://www.scientificamerican.com/



https://www.dw.com/en/plastics-to-outweigh-fish-in-oceans-by-2050-study-warns/a-18990459

E-waste



https://www.governancenow.com/news/regular-story/can-we-handle-our-ewaste

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Photoresist (e.g., **polymers**)
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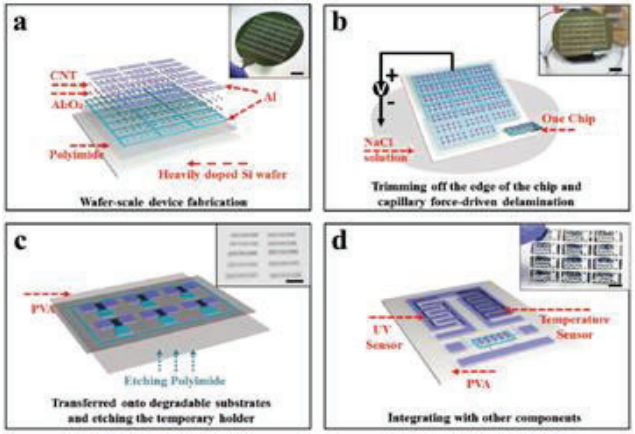
Cases (e.g., **polymers**)

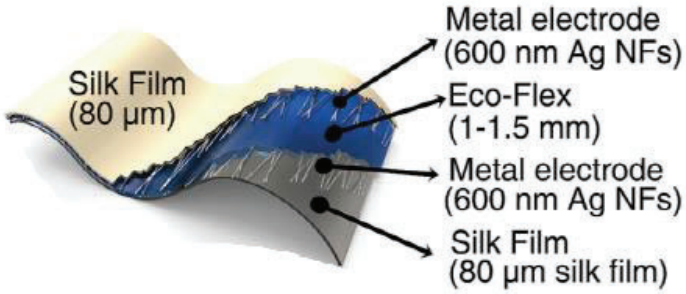
Green Electronic Materials

Polyvinyl alcohol (PVA)



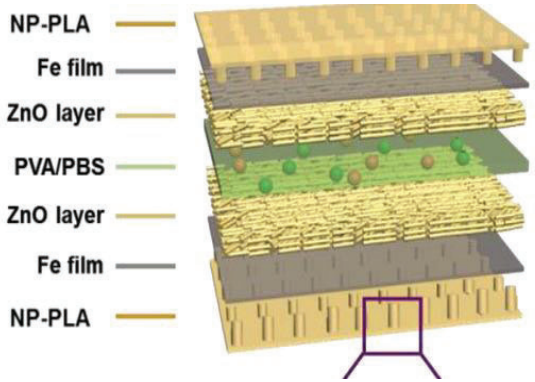
Youfan Hu et. al
Adv. Funct. Mater. 2019

Silk fibroin



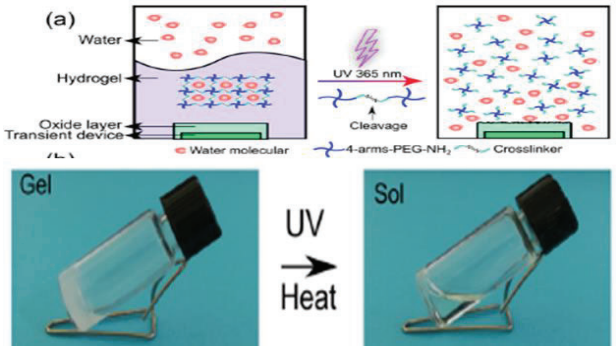
Guo Wenxi et al
Small 2019

Polylactic acid (PLA)



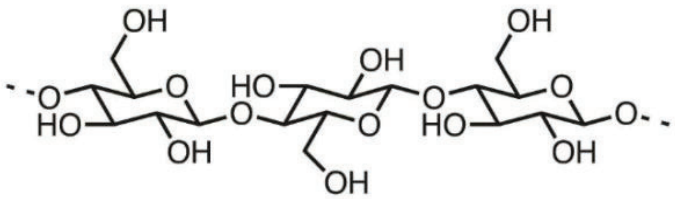
Zhou Li et al
Adv. Sci. 2019

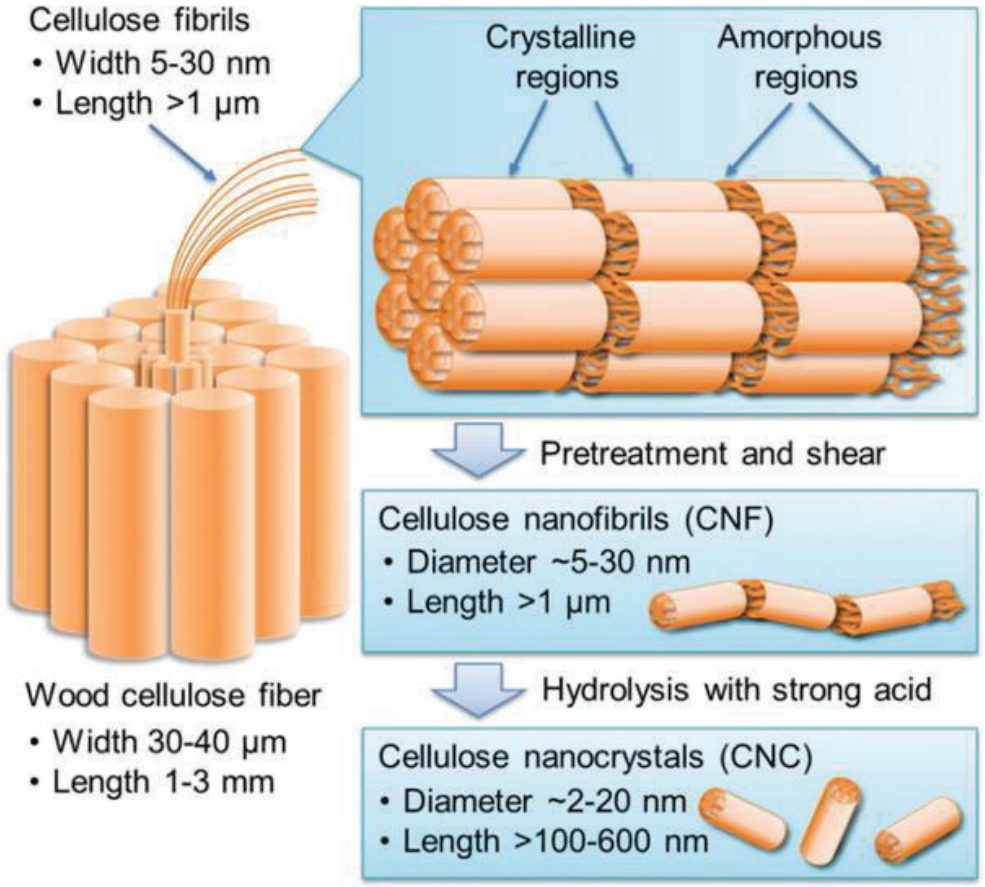
Polyethylene glycol (PEG)



Rong Zhao et al
ACS Appl. Mater. Inter. 2018

Nanocellulose

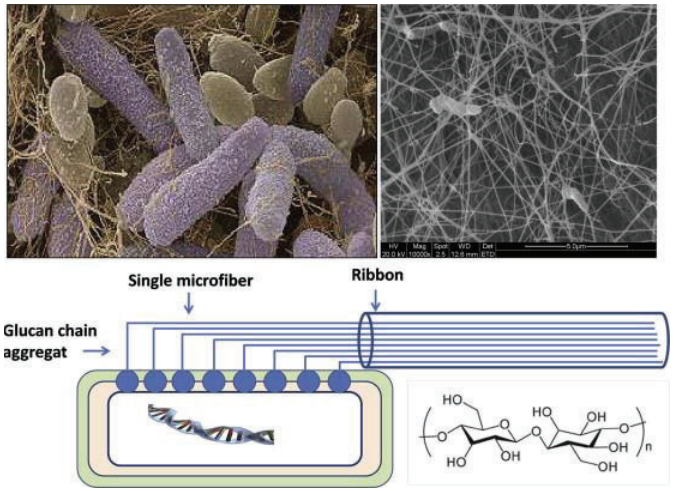




DOI: 10.5772/intechopen.77025

Nanocellulose from Natural Waste?

Bacterial cellulose



https://doi.org/10.1016/j.foodhyd.2013.07.012

Rice straw

Sea pineapple

Other Natural Waste Materials from Ocean

Polymers for Future Electronics

Part I. Human-friendly electronics

https://spectrum.ieee.org/biomedical/devices/

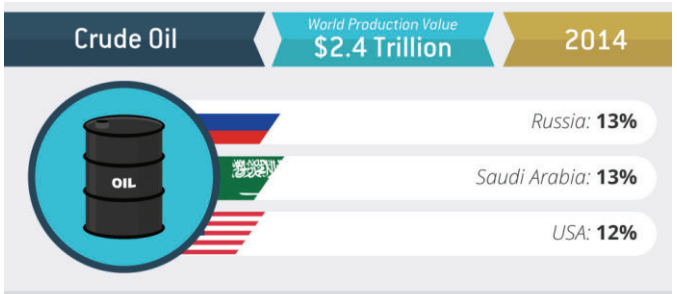
Part II: Green electronics

M. Irimia-Vladu, Chem. Soc. Rev., 2014

Conclusing remarks

Rankings of Industrial Raw Materials

1



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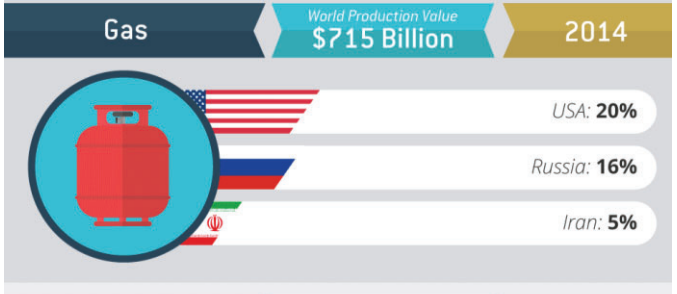

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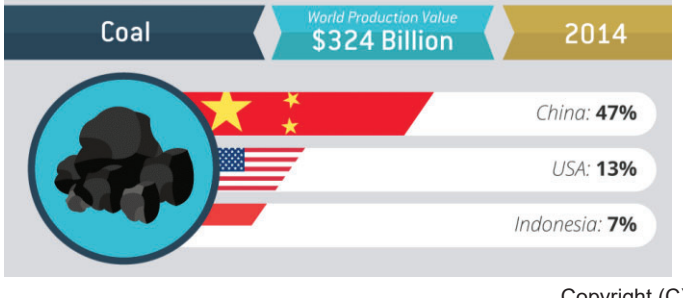

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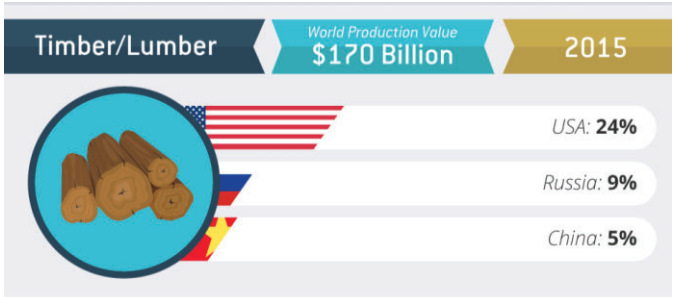

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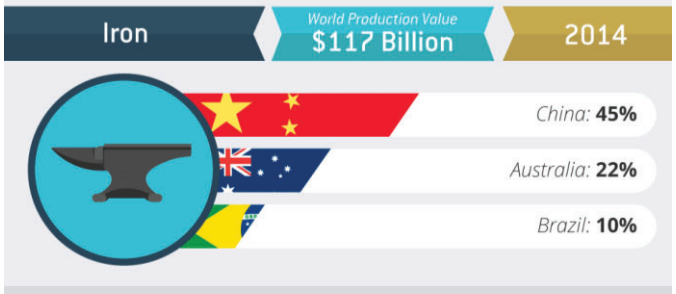
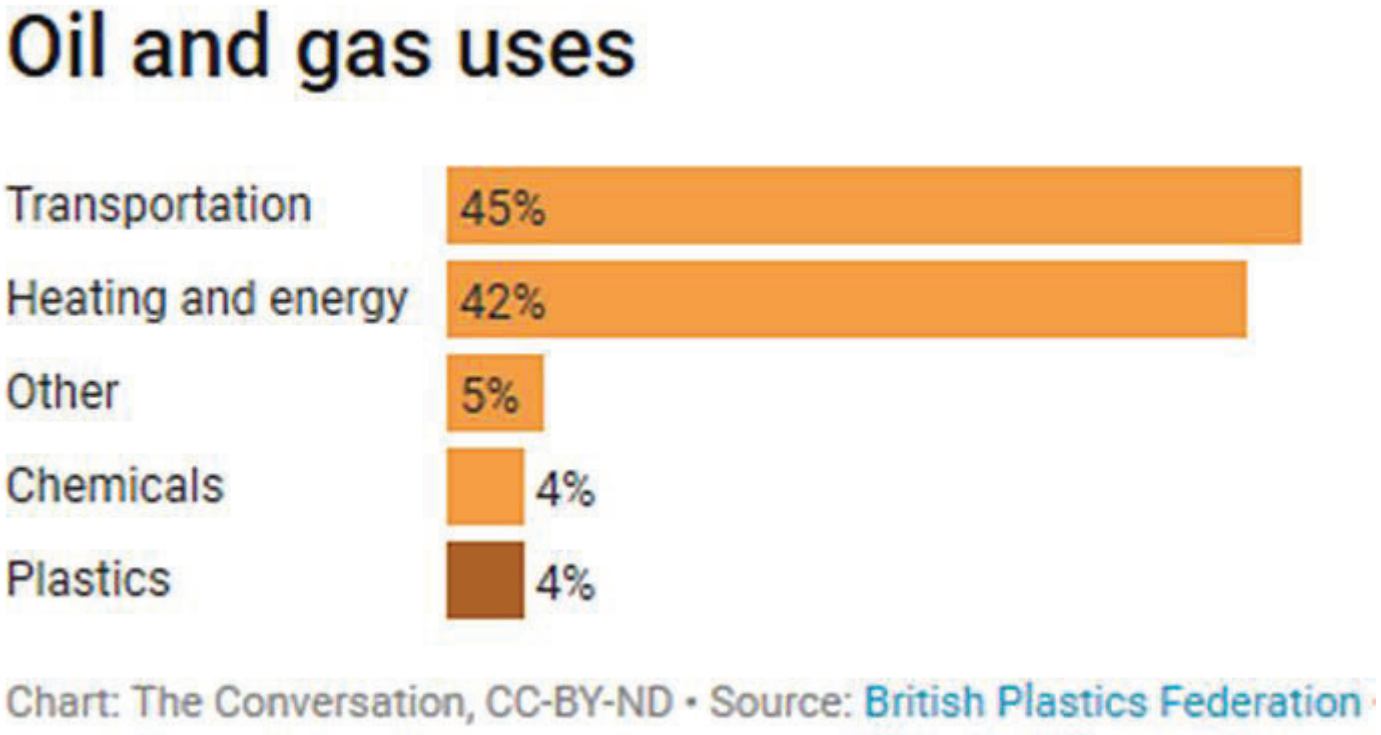


8

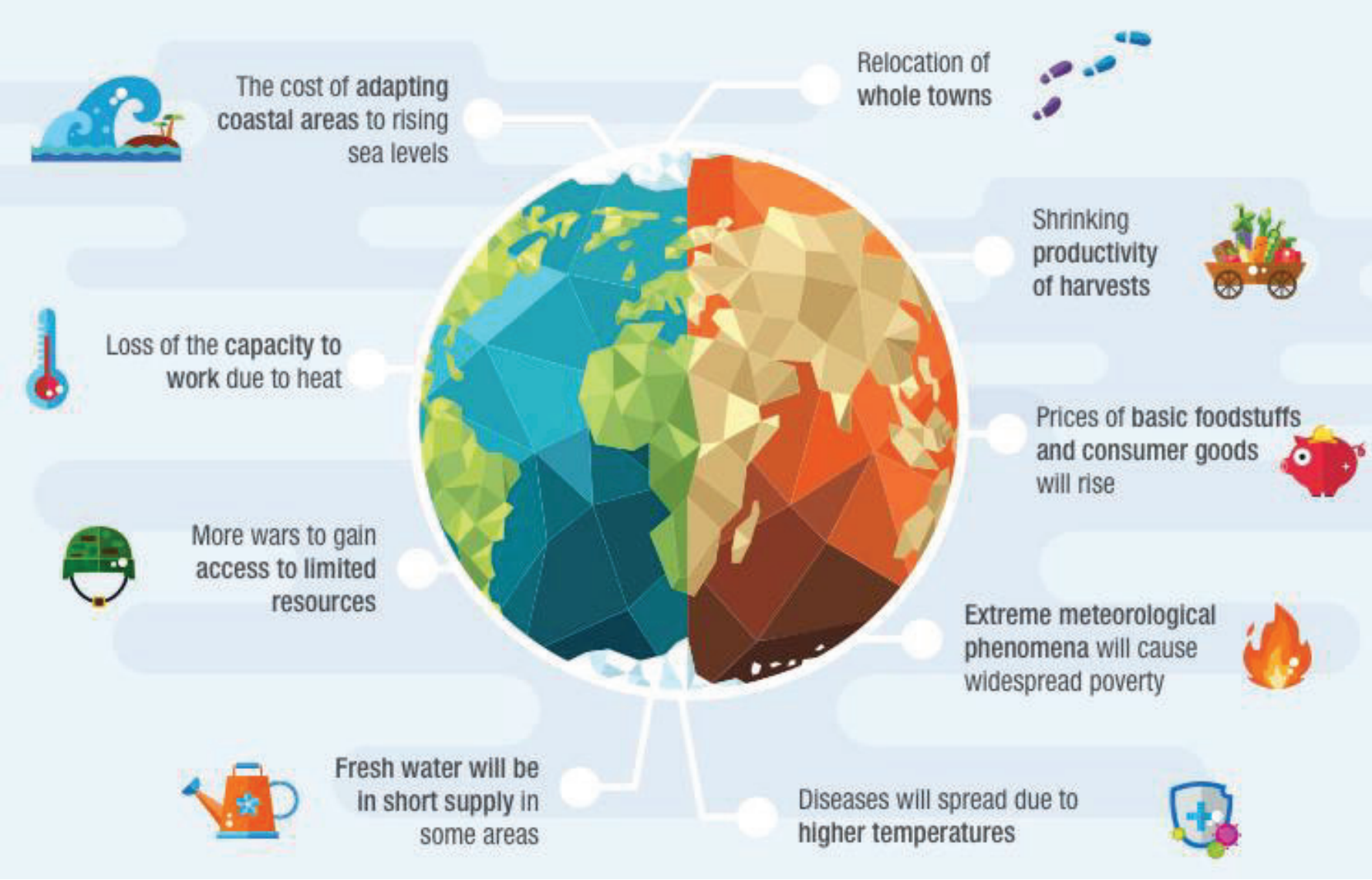
https://www.businessinsider.com/where-commodities-come-from-2016-11

World Oil and Gas Uses



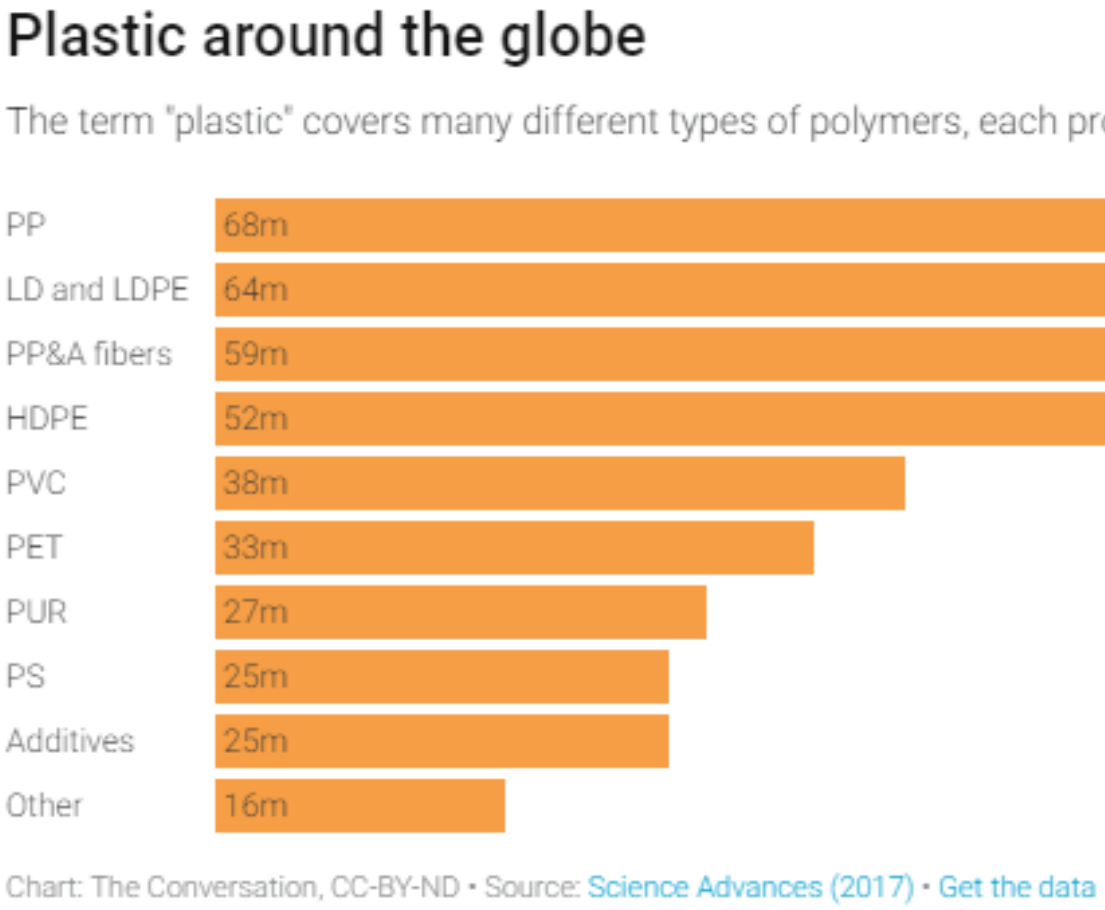
https://plastics.com/polymer-news-technology-today-world-production-of-plastics/polymer-news-technology-today-oil-gas-uses-700x525/

Fossil Fuel Dependence: Climate Change and Air Pollution



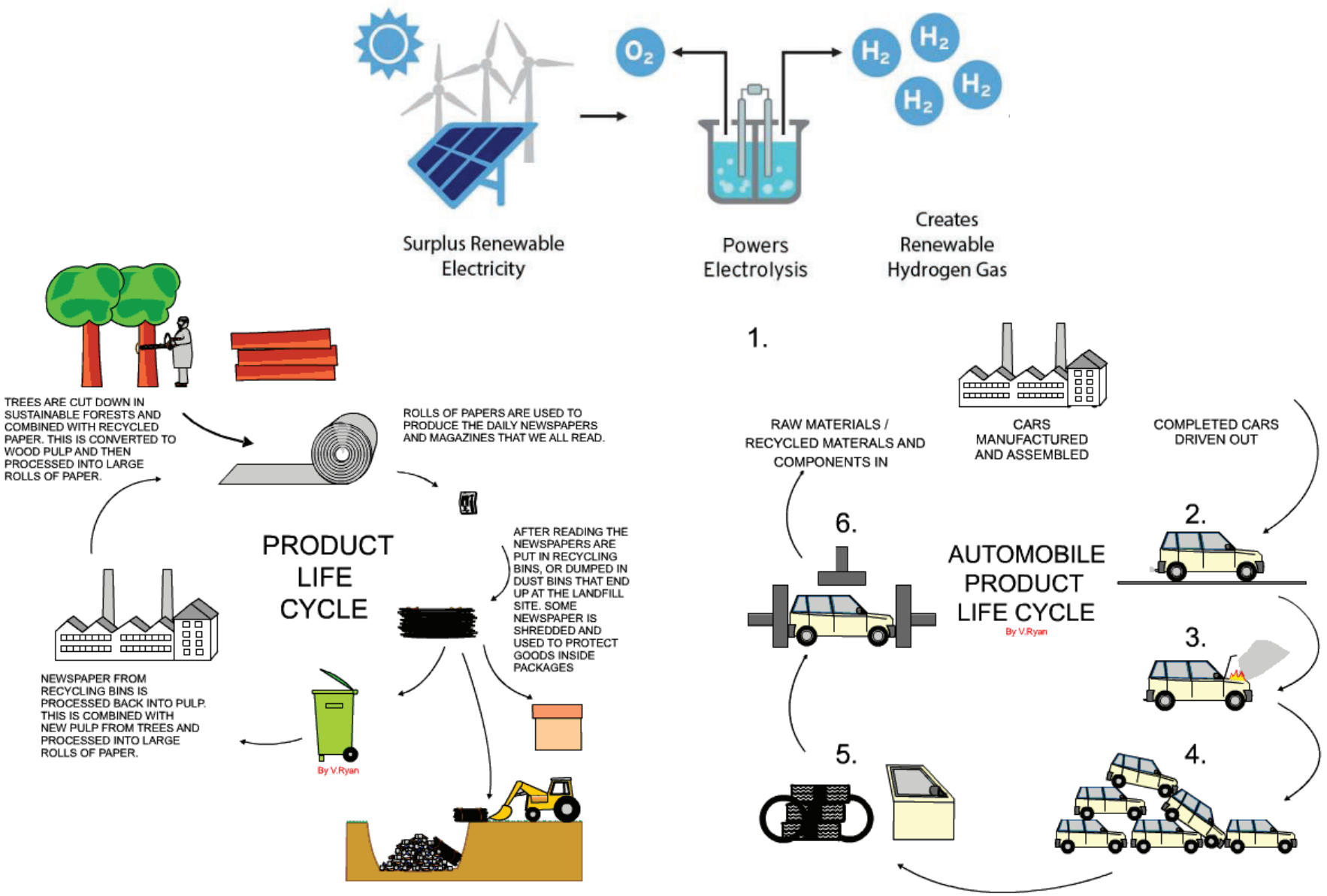
https://www.iberdrola.com/environment/impacts-of-climate-change

Commercial Plastic Production



https://www.weforum.org/agenda/2018/08/the-world-of-plastics-in-numbers

Renewable Energy and Materials



https://technologystudent.com/prddes1/lifecy1.html

Thanks for Your Attention