Chemical Engineering as an Academic Major and a Career

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Thanks to Ed Maginn for part of the this talk

Outline

Overview of chemical engineering

Impact of chemical engineers on society

What chemical engineers do

A little about what we study to be chemical engineers

Recap from yesterday

- Engineering involves fundamental science – to the extent necessary -- and then using mathematical analysis to get quantitative predictions for how a process or device will work… before we even build it!
- A challenge for "renewable" energy is that storage technologies are expensive and have limited capability
  - Today, large scale storage is best done by pumping water up a hill!
  - Also, not said, but solar, wind, biomass take vast land areas
- Important societal challenges exist for engineers to work on!

We can start with a *Definition*

- **www.dictionary.com**

- chemical engineering **(km-kl nj-nîrng)**
- ***n.***

- **The branch of engineering that deals with the technology of large-scale chemical production and the manufacture of products through chemical processes.**
- **----------**
- chemical engineer ***n.***

Traditional chemical/petroleum industry

Traditional chemical/petroleum industry

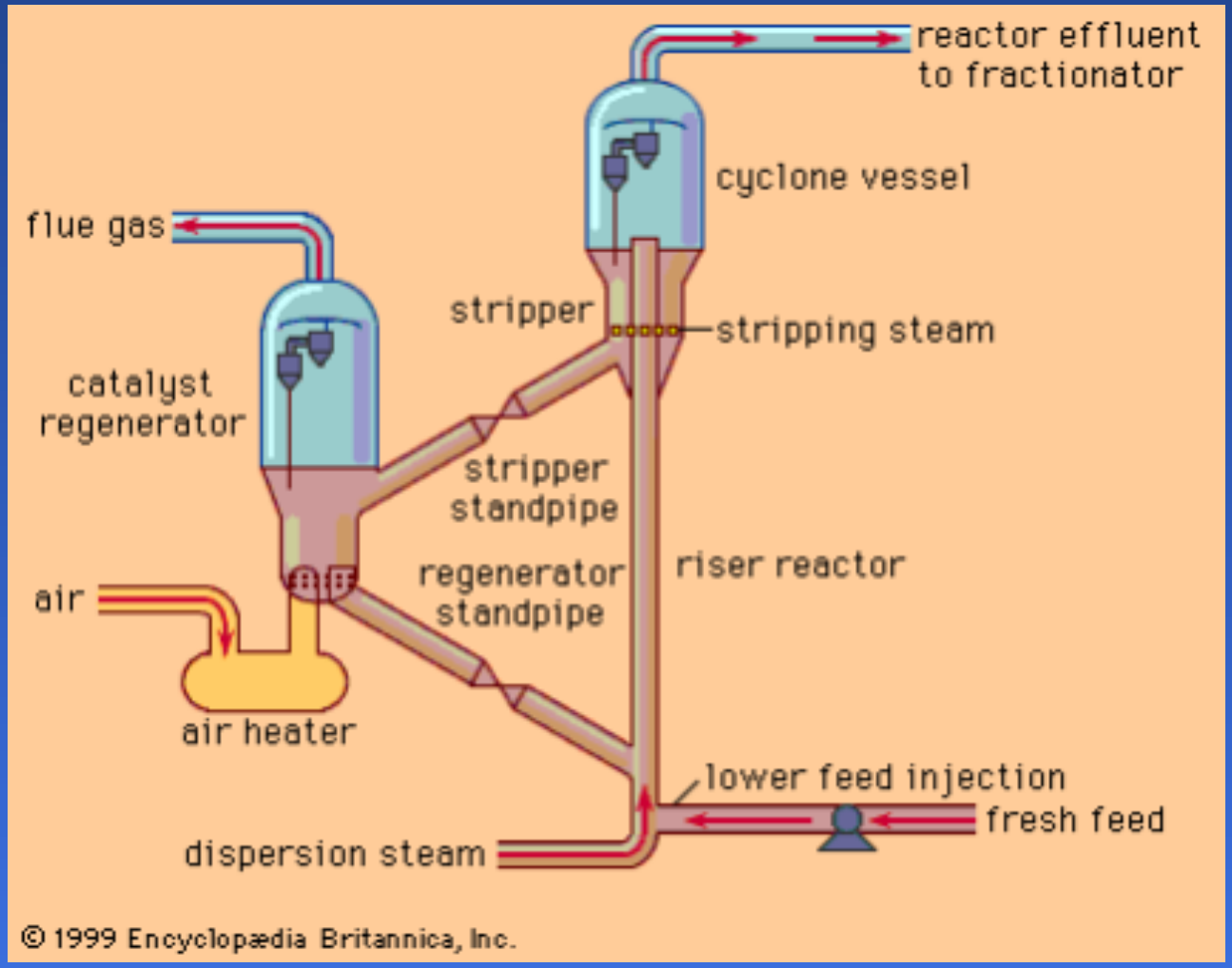
Large distillation tower

Traditional chemical/petroleum industry

Fluidized bed Catalytic Cracking unit

http://www.luboil.com/brief/brief.html

Cartoon of "Cat Cracker"



What is chemical engineering?

- ***Chemical Engineering*** **originated with the need to transform raw materials into useful products through chemical reactions.**
- **The reactions were discovered by chemists starting in the 1600's and by the end of the 1800's, there was a need to produce large quantities of an ever increasing number of materials.**
- **The "scale-up" of a laboratory reaction (~grams) to a profitable commercial process 10^6 grams) is usually not a matter of just making bigger laboratory equipment (flasks, beaker and Bunsen burners).**

Major problems solved by chemical engineers

- "The American Institute of Chemical Engineers (AIChE) has identified the 10 most outstanding achievements of chemical engineering as being:
- 1.production of fissionable isotopes,
- 2.production of synthetic ammonia,
- 3.production of petrochemicals,
- 4.production of chemical fertilizers,
- 5.commercial-scale production of antibiotics,
- 6.establishment of the plastics industry,
- 7.establishment of the synthetic fibers industry
- 8.establishment of the synthetic rubber industry,
- 9.development of high-octane gasoline,
- 10.electrolytic production of aluminum.

Primary characteristics of chemical engineers

- **Chemical** engineers understand matter in terms of its fundamental nature,
  - i.e., molecules,
  - can describe molecules or groups of molecules *quantitatively*
- They use *molecular understanding* to deal with processes involving chemical, biological and physical *transformations* of matter
- To effectively do this, they can answer the important questions necessary to bridge the gap from molecular sizes up to the dimensions of everyday life.

Today

- Dynamic profession that touches nearly all aspects of our lives
- Materials
  - Polymers, composites, electronics
- Energy
  - Fossil fuels, photovoltaics, nuclear
- Environment
  - Catalytic converters, clean water, pollution prevention
- Human health
  - Tissue engineering, pharmaceutical production, medical devices
- Food
  - Agricultural chemicals, food production and preservation
- Safety
  - New materials for vehicles, personal protection, chemical process safety

Tomorrow: solar to liquid fuel?

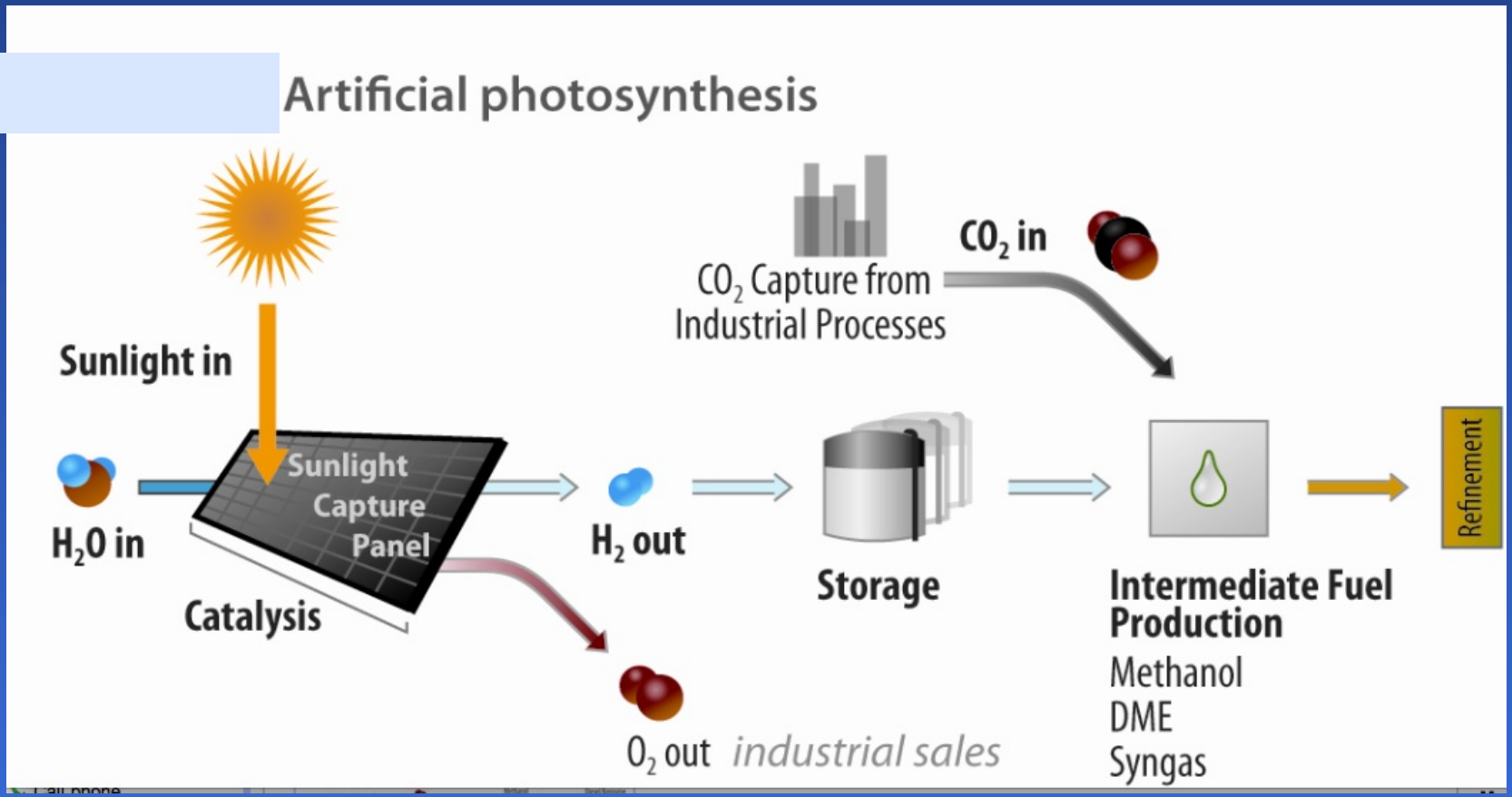


Image from Research Triangle Solar Fuel

Separations and Materials

1945: Gaseous diffusion plant to separate U-235 (1%) from U-238 (99%).- Image from Oak Ridge National Lab

Today: hollow fiber reverse osmosis membranes for water purification (DuPont)

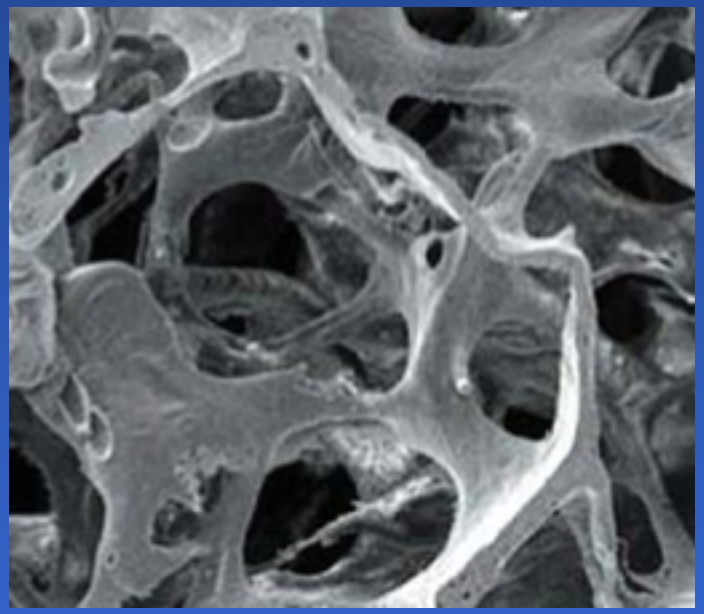
Separation Processes, Thermodynamics, Transport Phenomena

- Perth desalination plant – 130 million liters/day

Polymers

Bakelite reactor (courtesy of Smithsonian Institution)

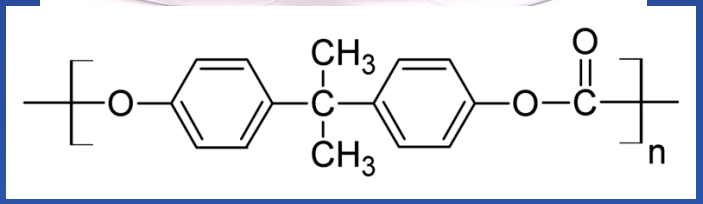
1910: Bakelite, the first synthetic thermosetting plastic, made from phenol, formaldehyde and wood flour.

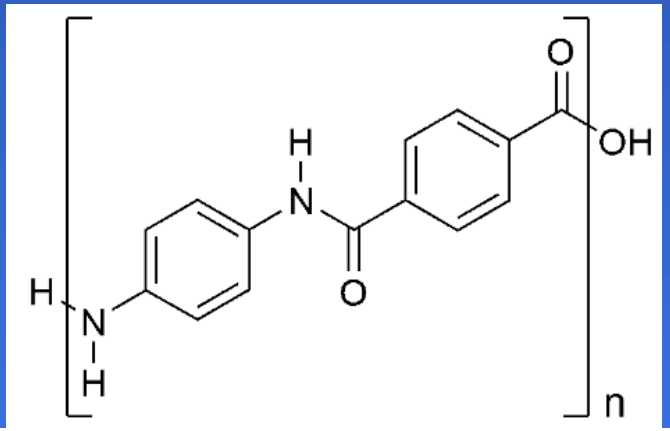


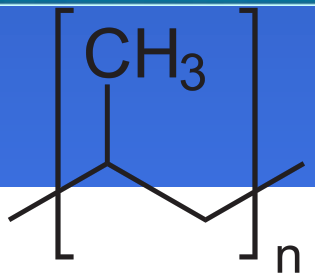
Today: biodegradable foam structure for bone regeneration (courtesy Univ. Toronto)

Materials, Biomolecular Engineering, Polymers

Materials for Safety

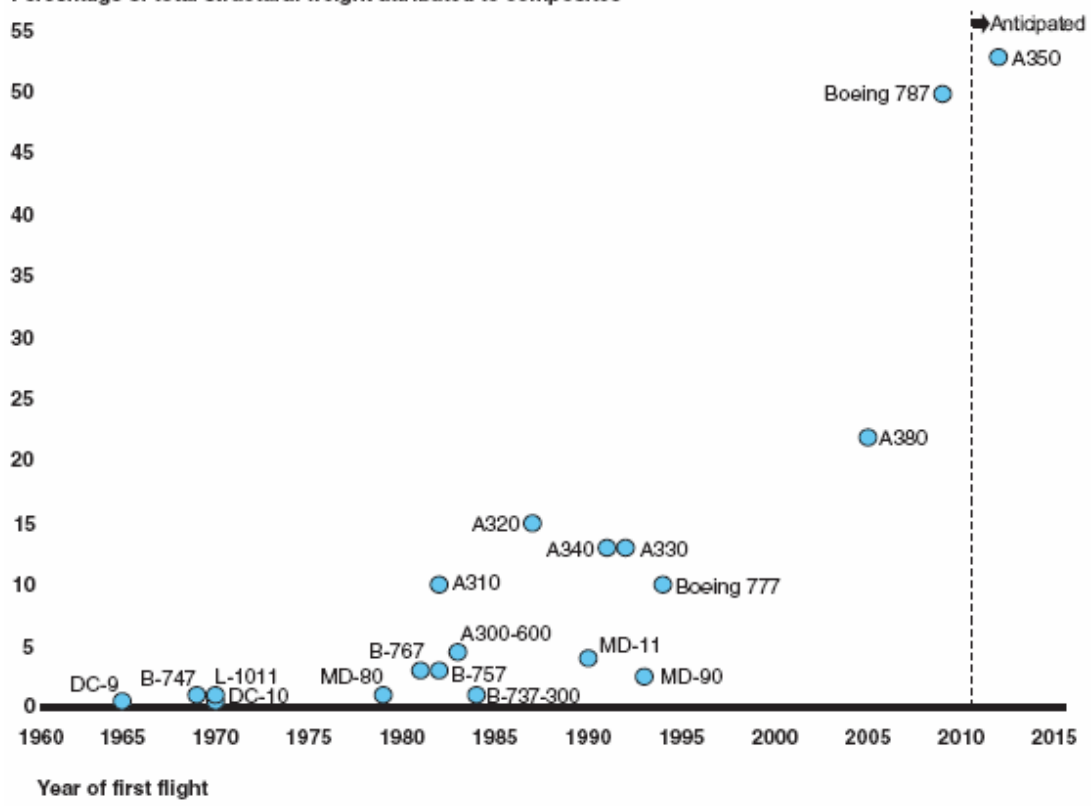




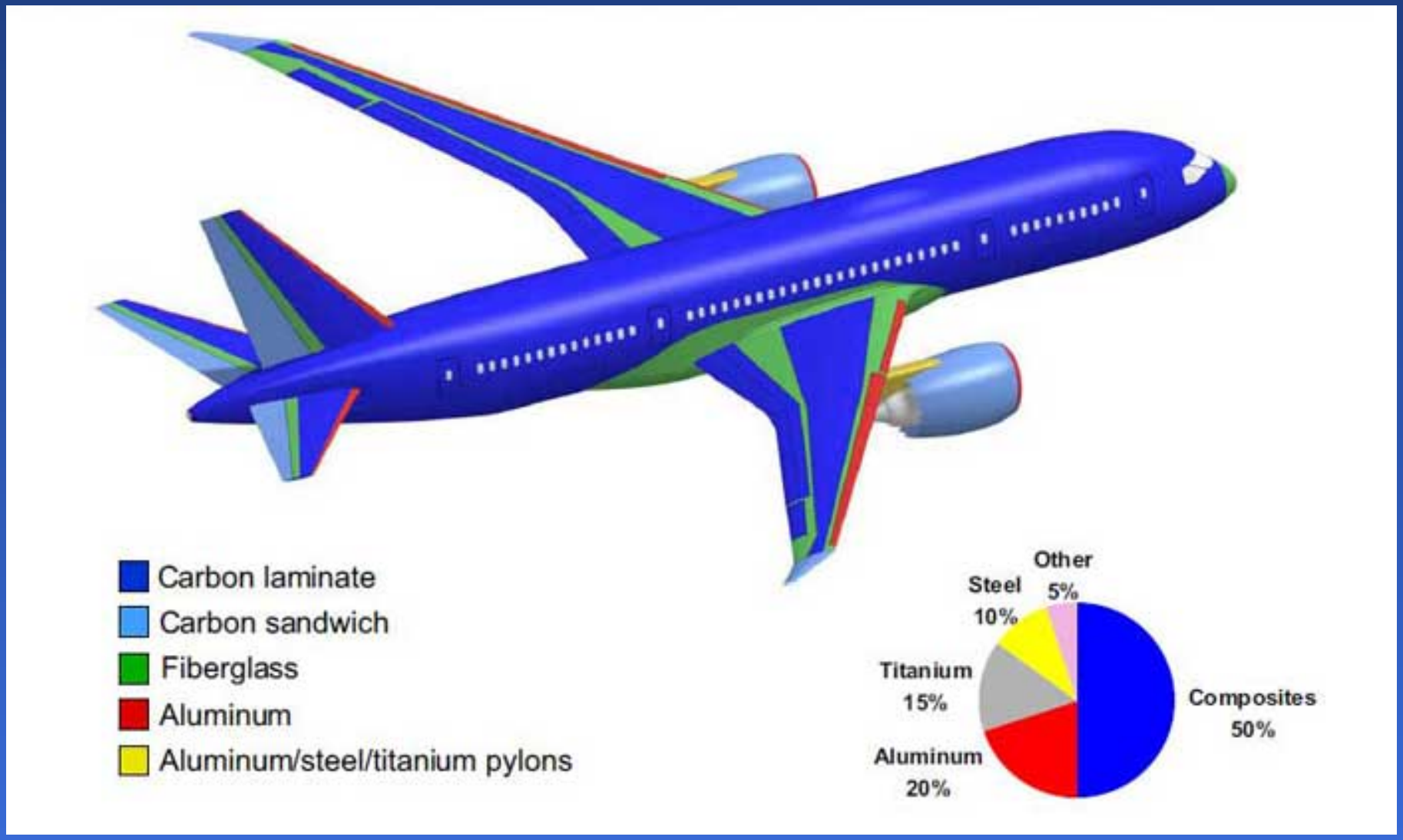


Aircraft increasingly made of composites

Figure 1: Commercial Airplane Models over Time by Percentage of Composites



Sources: GAO analysis of information from FAA, NASA, Boeing Company, *Jane's All the World's Aircraft*, and *Jane's Aircraft Upgrades*.


Carbon laminate
Carbon sandwich
Fiberglass
Aluminum
Aluminum/steel/titanium pylons
Other
5%
Steel
10%
Titanium
15%
Aluminum
20%
Composites
50%

Boeing

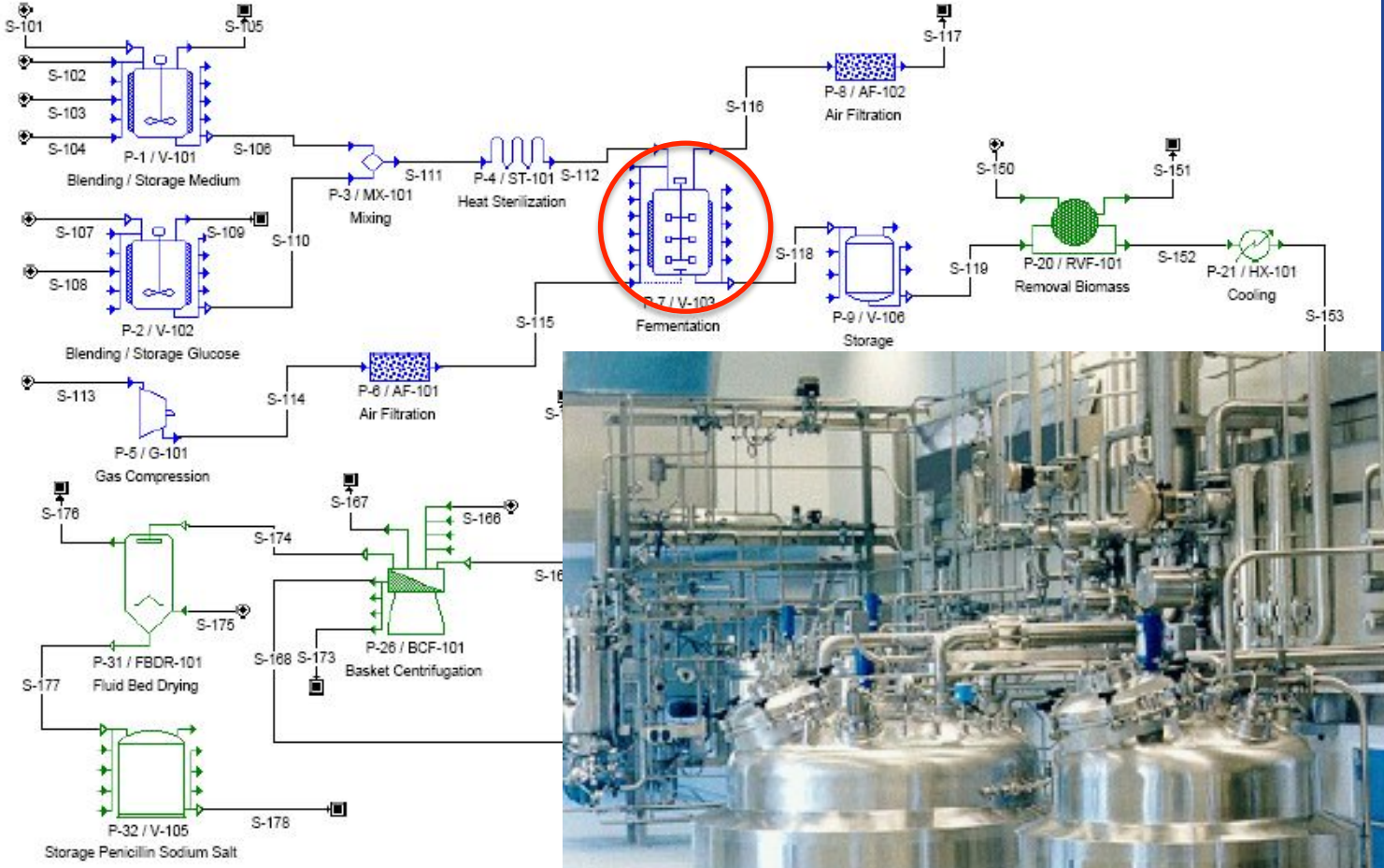
Bioengineering

- **Early on, penicillin production was lab-scale**

1943: a chemist investigates a stack of glass flasks, each containing enough penicillin mold for a single dose

Image from Pfizer

Process Flow Diagram: Penicillin



Images: creative

Brain Cancer implantable "patch"

http://www.guilfordpharm.com/fs_products_f.htm

Also on the horizon

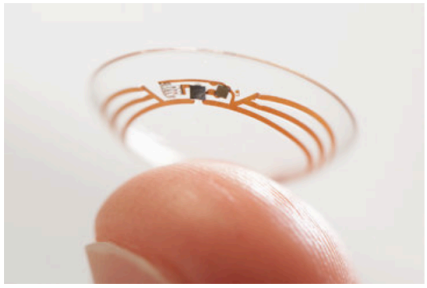
- **New drug delivery technologies**
  - **Insulin pump: artificial pancreas**
  - **Other feedback control systems for drug administration**
  - **Addition of special ligands onto small molecule drugs to get them to bind at specific locations**
  - **Combined constructs of drug molecule and specially chosen particle size that help target delivery to specific locations (aerosols)**

Glucose monitor?

INTERNATIONAL BUSINESS

Novartis Joins With Google to Develop Contact Lens That Monitors Blood Sugar

By MARK SCOTT JULY 15, 2014



The lab known for self-driving cars is making a contact lens to measure glucose in tears.
Google, via Agence France-Presse — Getty Images

EMAIL

LONDON — Google announced on Tuesday a partnership with the European drug maker Novartis to develop a smart contact lens with the potential to monitor the wearer's blood sugar levels.

The agreement is among recent moves into the health care sector by technology giants including Apple and Samsung as they develop devices and mobile applications to track people's daily lives.

Novartis said that Alcon, its eye care unit, had struck a deal to license so-called smart lens technology from one of Google's research divisions. Financial terms were not disclosed.

Nanoparticles for cancer therapy

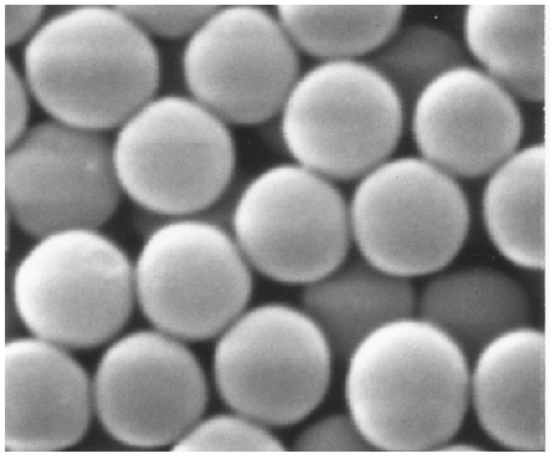
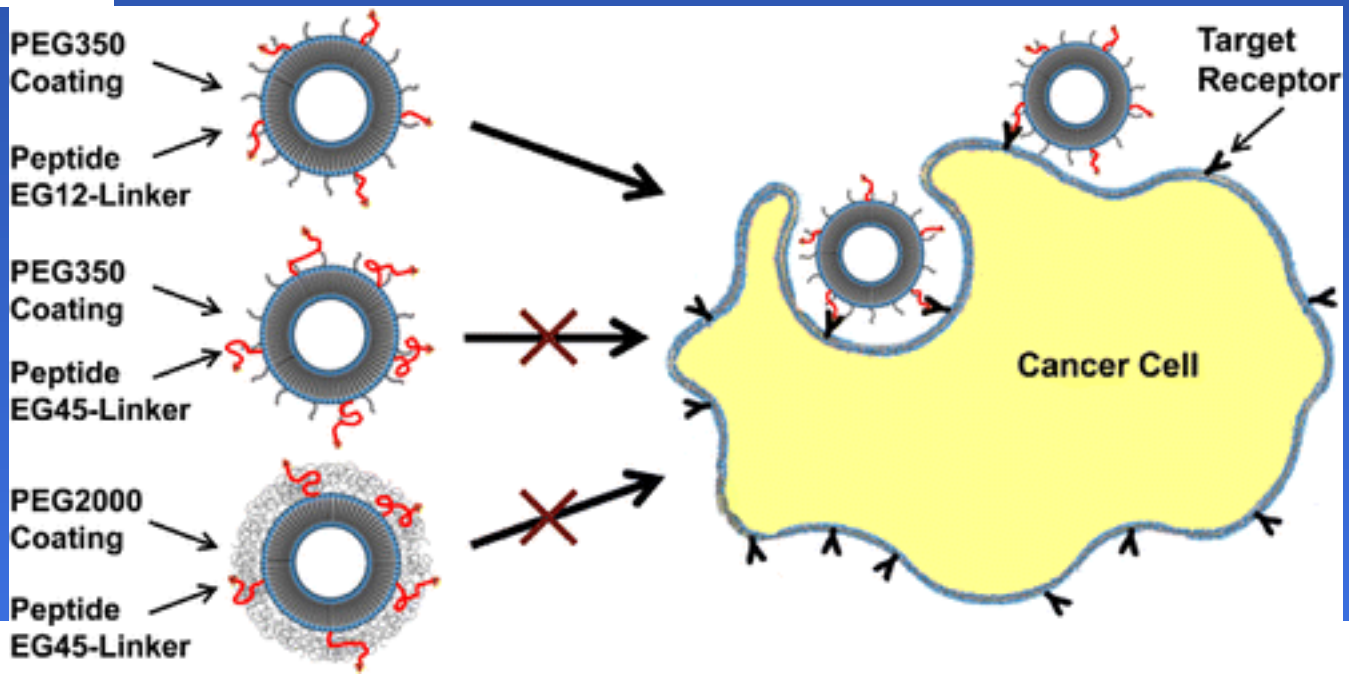


Image: Cancer Research UK

Image: Prof. Z Bilgicer, Univ. of Notre Dame



What do CBE graduates do?

- **Examples of career paths of Notre Dame CBE grads**

Shawn O'Grady ChEg '86

- **Currently: VP Consumer Food Sales, General Mills**
  - **Air Products for 2 years**
  - **Harvard MBA, 1990**
    - **Chose General Mills over ICI, DuPont, Air Products and Monsanto**
  - **Several awards from General Mills, manages 250 people with $2Bil in revenue**

Melanie Sanchez-Jones ChEg ‘89

- **Recently:Manager, Global Employee Benefits, Air Products and Chemicals**
  - **24 years at Air Products with jobs: Product manager, University relations, New product commercialization, Product marketing**
  - **MBA Lehigh, 1998**

Joseph McCarthy, ChEg ‘93

- **Professor and William Kepler Whiteford Faculty Fellow, Department of Chemical and Petroleum Engineering**
  - **Research interests: transport phenomena in particulate and/or discrete systems.**

Brian Fitzpatrick
ChEg ‘97

- **Currently Professor at Vanderbilt Law School**
  - **Harvard Law School (graduated #1)**
  - **Clerk for Anthony Scalia**
  - **Private Law firm in Washington**
  - **Special Counsel for Supreme Court nominations for a US senator**
  - **Areas of Expertise**
  - Civil procedure, appellate litigation, federal courts, the Supreme Court, constitutional law

Jennifer Ehren ChEg ‘99

- **Medical researcher**
  - **ND Valedictorian**
    - **Not always a ChEg!**
  - **ACE program 2 years**
  - **Merck for 2 years**
  - **Graduate School at Stanford**

Andrew Downard ChEg,' 03 MBA '04

- Currently graduate student at Caltech
  - Not based on long term plan
- Business partner with three of us -- helped with a small startup company for a couple of years
  - Other faculty realized the value of an "Andy"

Sarah Keefer ChEg ‘04

- Currently in medical school at St. Louis University
  - One year at Accenture
  - Varsity athlete (rowing)
  - Missed the first semester for chemical engineers to study in Spain

Eric Sauer ChEg '05

- **Currently a graduate student at Wisconsin**
  - **One of few students to pass all of the qualifying exams at UW on the first attempt.**
  - **Graduate school was not original plan -- spurred by doing research**

Pamela Jefson ChEg ‘06

- **Global Operations Leadership Development (G.O.L.D) Program, Johnson & Johnson**
  - **Manufacturing engineering with Ortho Clinical Diagnostics (OCD), Rochester, NY**
  - **Had been a quality engineer in a manufacturing facility in Juarez, Mexico -- Ethicon Endo-Surgery**

Lauren Flocare ’09

- **Associate Scientist, Paragon Bioservices Inc. (Baltimore, MD)**
- **Manages fermentation lab**

Chris Hensler '13

- Rotational Engineering program, Lummus Technology, Houston, TX
  - First assignment: Randall Gas business
- CBE graduation speaker; active in Tau Beta Pi, AIChE, Joint Engineering Council…
- Process Engineering Intern, Carnegie Strategic Design Engineers, LLC (Pittsburgh)
- Study Abroad, Universidad Politecnica da Valencia, Spain

What do chemical engineers learn about to become one?

- **Fundamental Science,**
  - **Mathematics, Chemistry, Physics, Biology**
- **Engineering science topics:**
  - **Chemical Thermodynamics**
  - **Transport Phenomena**
- **Integration of these in courses such as**
  - **Reaction Engineering, Separation Processes and Process Design**

OPTION "A" - STANDARD CURRICULUM

	FALL		SPRING		
FRESHMAN	MATH 10550, Calc I	4	MATH 10560, Calc 2	4	
	CHEM 10171/11171	4	CHEM 10122	3	
	EG 10111 Intro to Eng	3	EG 10112, Intro to EG	3	
	Arts & Letters 1	3	PHYS 10310, Gen Phys 1	4	
	University Sem-A&L 2	3	University Sem-A&L 3	3	
		17		17	
SOPHOMORE	MATH 20550, Calc 3	3.5	MATH 20580, Linear/ODE	3.5	
	CHEM 10172/11172 Org 1 & Lab	4	CHEM 20273, Org 2	3	
	CBE 20255 or CBE 30385, Intro to Chem/Bio Eng	3	CBE 20260, Thermo I	3	
	PHYS 10320, Gen Physics 2	4	CBE 20258, Comp Methods	3	
	A&L 4	3	A&L 5	3	
			CBE 20290, Career Choices Eng	1	*Recommended
		17.5		16.5	
JUNIOR	MATH 30650, Differential Eq	3	CHEM 30324, Pchem	3	
	CHEM 30333/31333 Achem & Lab	4	CBE 30338, Chem Proc Control	3	
	CBE 30355 or CBE 30357, Transport I or Biotransport	3	CBE 30356, Transport 2	3	
	CBE 30367, Thermo 2	3	CBE 31358, Chem Eng Lab 1	3	
	CBE 30361, Materials	3	A&L 6	3	
		16		15	
SENIOR	CBE 40443, Separations	3	CBE 40448, Process Design	3	
	CBE 40445, Reaction Engineering	3	CBE Elective	3	
	CBE 41459, Chem Eng Lab 2	3	Tech Elective	3	
	CBE Elective	3	Advanced Science Elective	3	
	A&L 7	3	A&L 8	3	
		15		15	

Summary

- Chemical engineering is a diverse field
- Emphasis on translation of advances in "molecular sciences" to practical use
- Integration of chemistry, mathematics and engineering (plus business, economics…)
- Is it right for you?
  - Enjoy chemistry, math, computer modeling
  - Problem solving; applying math and science
  - Wide array of career options
- ND Engineering puts you in elite company
- Questions / discussion???

Summary

- **To summarize**
  - **The ability of chemical engineers to deal with chemical nature of materials from molecular to macroscopic length scales makes them unique.**
  - **These skills can be used in a number of areas outside of the chemical processing industries**
  - **The inherent breadth of the curriculum and our focus on understanding *why*, allows our graduates to make major impacts in a diverse range of fields where the ability to analyze problems quantitatively is important!**