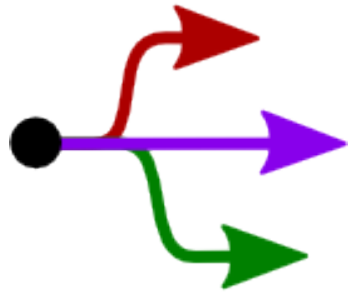
Separation Processes

ChE 4M3



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Revision number:11 (September 2012)

Last class (06 September 2012)

- We covered the admin issues
- Grading
- And in particular what is appropriate group work

Overview of Separation Processes

- Why study separation processes?
- Economics of separation processes
- Some everyday examples
- Example flowsheet: Sugar production
- Separating agents
- Classification of separation processes

Why separate?

- Can't beat Nature: "Second Law of Thermodynamics"
  - salt left in water
  - CO_2 pumped into the atmosphere
  - pollutants dumped into water
  - and even the kitchen sink

How to separate salts from water

- electrodialysis
- electrodeionization
-
-
-
-
-
-

Reference: King, p 16

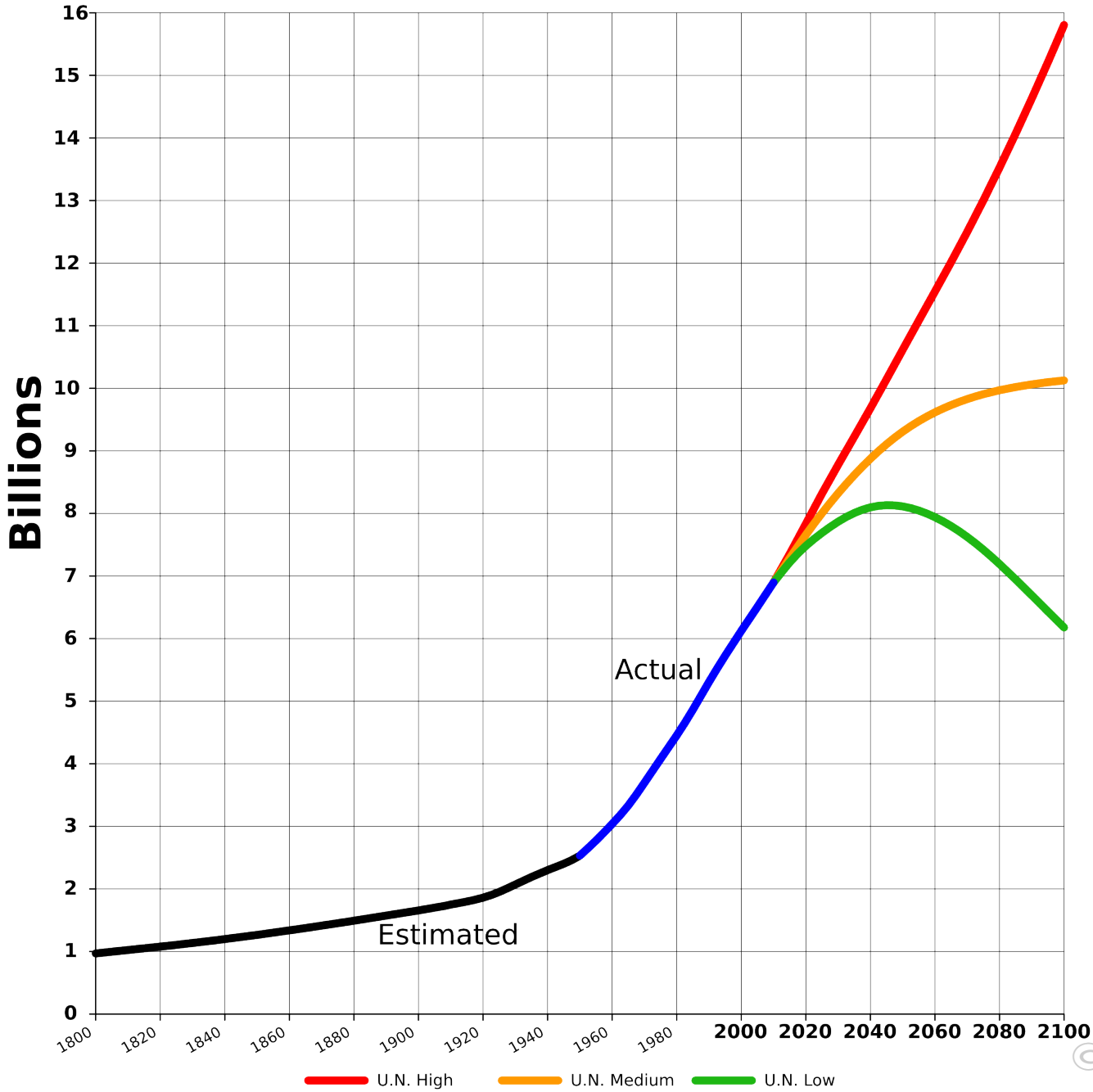
Usually there are multiple ways to achieve a required separation.

Why study separation processes?

- 50% to 90% of capital investment on petroleum and other chemical-reaction based flowsheets [King, p 15]
  - Expense often in proportion to the level of purity (called the separation factor) [Treybal, p 2]
- 60 to 100% of the ongoing operating costs in chemical plants
- Some important problems facing (the global) "us" are **separation problems**:
  - carbon capture and sequestration/storage (CCS) ... don't forget about methane
  - other air pollutants (e.g. cleaning small dust particles $\sim 5\mu$m)
  - access to clean water/sanitation

These problems will be an important part of your career, and impact your life, as the world's population approaches 8, 9 and then 10 billion in our lifetime (expected around 2050 to 2080).

World population: UN projections



Everyday examples

Separation processes at home:

- screening: sieve to strain water from pasta
- absorption: washing dishes/hands (fat dissolves into non-polar branch)
- liquid/liquid extraction: soak spices in oil to extract flavour
- cyclone:
- filter:
- leaching:
- leaching:
- adsorption:
- centrifugation:
- phase change by heat addition:
- phase change by heat removal:

Everyday examples

Separation processes in your body:

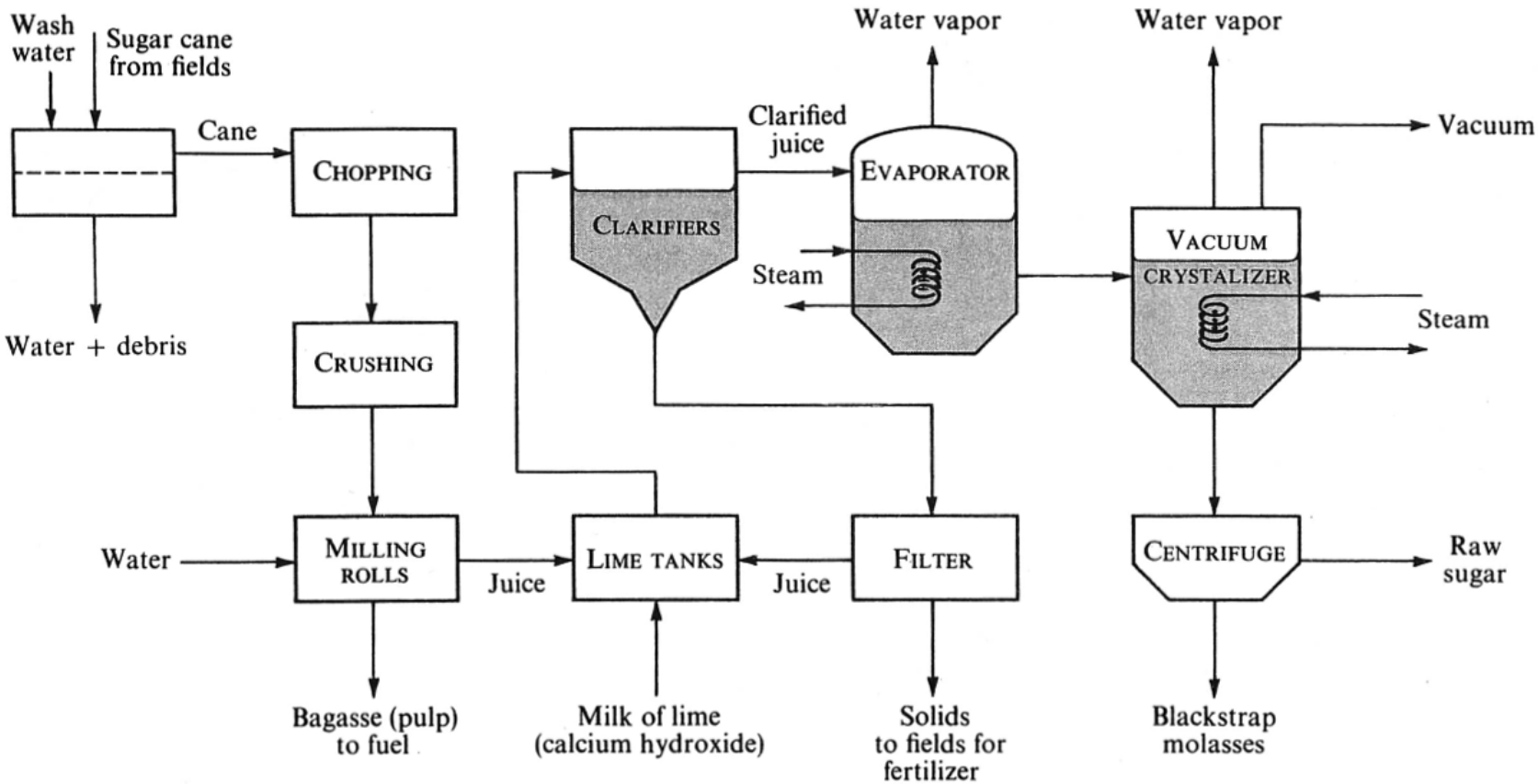
- kidneys: separates waste from blood; reabsorbs water and salts back into blood
- lungs: release of CO_2 from blood
- liver: breaks down toxins, excreted into bile
- gallbladder: concentrates bile
- intestines: absorb nutrients
- spleen: removed old red blood cells
- lymph nodes: filter foreign particles (e.g. cancers)

Engineering example

A common, everyday substance: sugar Video

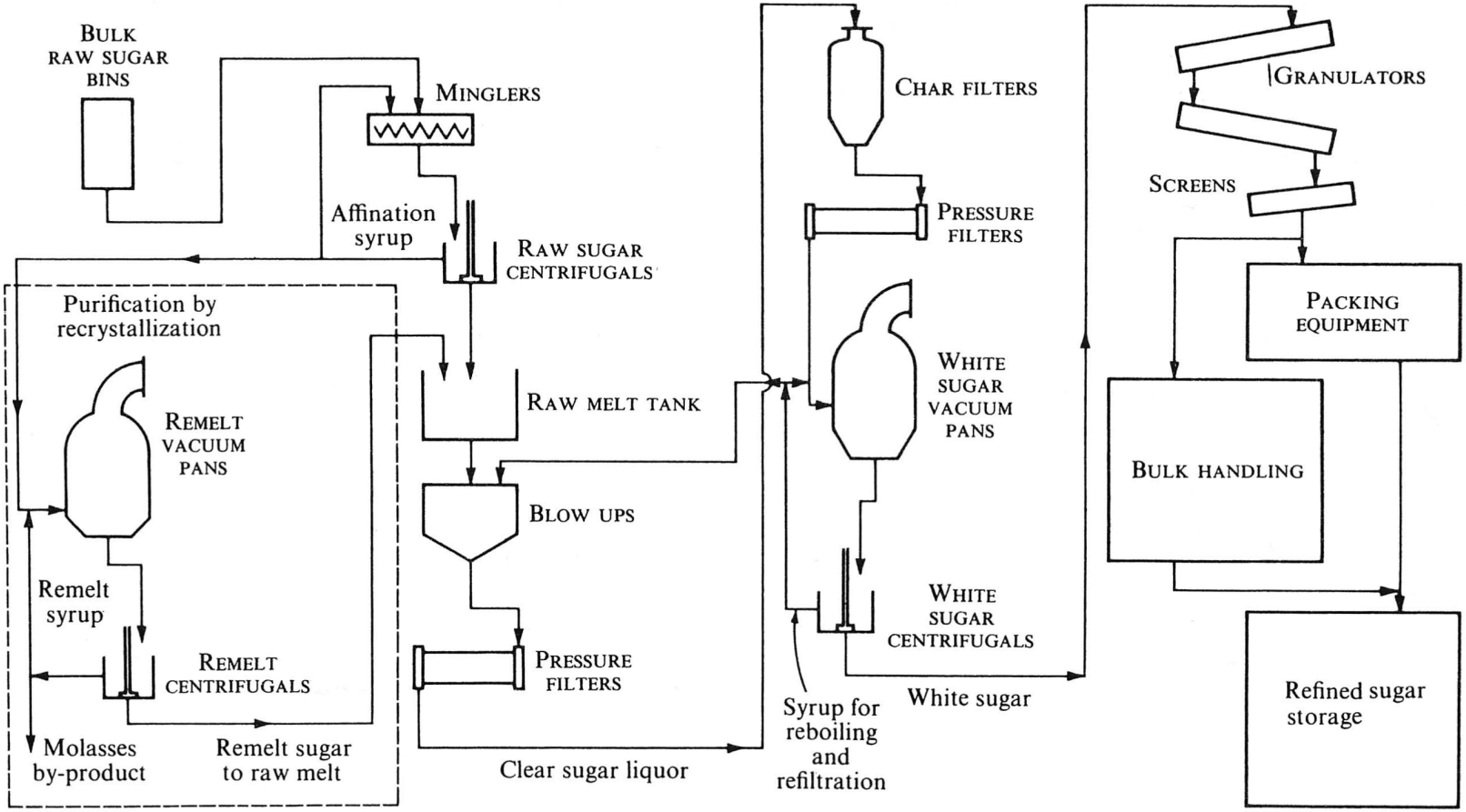
http://www.youtube.com/watch?v=ZBOou6cahtw

Sugar flowsheet (part 1)



Source: C.J. King, Separation Processes

Sugar flowsheet (part 2)



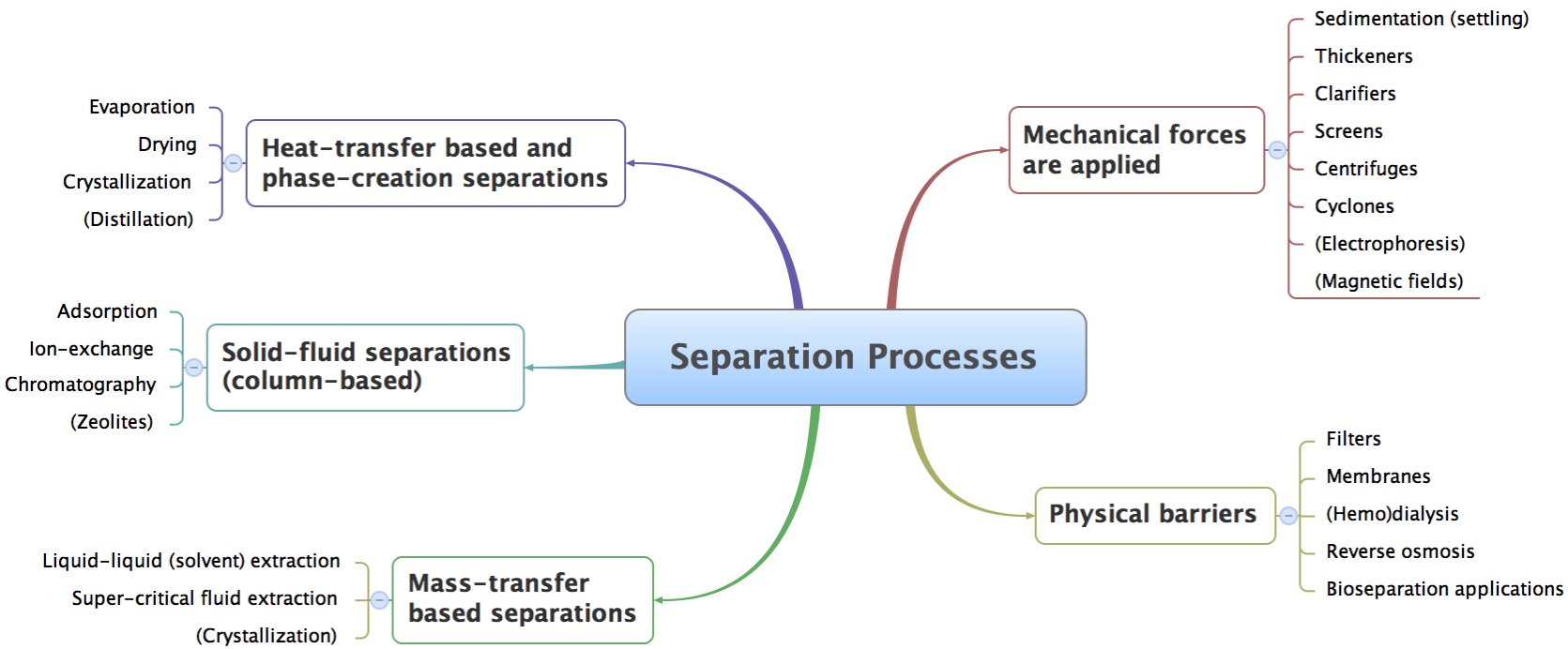
Source: C.J. King, Separation Processes

Topics that you want to cover

Based on the class activity yesterday, from highest to lowest:

- Reverse osmosis
- Membranes, including (hemo)dialysis and pervaporation
- Distillation
- Centrifuges
- Cyclones
- Filtration (various types: regular, ultra-, nano-)
- Juicing (has relationship to bioseparation steps)
- Ion-exchange
- Crystallization
- Chromatography
- Electrophoresis
- Zeolites
- Column-based operations: stripping, absorption, packed beds
- Interesting: petro fracking, hydro-fracking, winnowing, demisters

Current plan for 4M3 in 2012



Bioseparations

- Many of the topics we will cover are part of a pure bioseparations course
- Often called "downstream" processing in the bio literature
- Only difference: they are operated under "bio-compatible" conditions: T, P, pH, aqueous media
  - i.e. all unit operations downstream of the bioreactors
- Unit operations include:
  - cell disruption: increase entropy!
  - centrifugation $*$
  - precipitation
  - adsorption and chromatography $*$
  - filtration $*$
  - membrane separation $*$
  - electrophoresis

$*$ = a topic we will cover in 4M3

In this regard, you can see bioprocess separations are naturally designed and operated by chemical engineers.

How this course is structured

- We aim to consider a variety of separation systems
- Solids and (liquids and gases) = fluids
- Cover unit operations that rely on:
  - mechanical techniques to separate
  - mass transfer
  - phase creation or addition
  - heat transfer
- For each unit operation we consider
  - the physical principle that causes separation
  - how to size the unit and specify it; scale-up issues
  - issues that affect the unit's cost
  - troubleshoot problems with the unit;
  - how to optimize it (e.g. use less energy, increase separation efficiency, modify an existing unit's purpose)

Separating agents: MSA and ESA

A material, force, or energy source applied to the feed for separation

i.e. what you add to get a separation

- heat
- pressure
- *there are many others*

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- *there are many others*

Tutorial question: another way of looking at separations

Fill in various separation processes in these 9 rectangles:

		MINOR COMPONENT		
		SOLID	LIQUID	GAS/VAPOUR
MAJOR COMPONENT	SOLID			
	LIQUID			
	GAS/VAPOUR			