# The role of chemistry in feeding the world

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# Assumptions

- Land available for agriculture will stay ~ constant
- Climate warming is broadly neutral on global yields
  - $CO_2$ raises water-use efficiency, some yields; $H_2O$ limits others; pests flourish
- World population will grow: 8bn by 2025, 9bn by 2050
- Affluence drives demand for meat, cereals, edible oils
- Current energy use, GHG emissions unsustainable

***≥50% more food required on same land area, with improved sustainability***

# Feeding the world is possible

- 50% more food possible in each of 4 ways
  - raise poor yields to the average by crop
  - eliminate food waste
  - stop eating meat
  - raise ocean productivity to ¼ land productivity
- Outcome likely to be a blend of these

# Climate change creates work for breeders

- More heat units
  - longer maturities
- Higher night temperatures
  - reduced respiration rate
- More extreme events
  - stress tolerance
- More pests, shifting spectrum

# Biologists have some "grand challenges", e.g.

- Nitrogen fixation
- More efficient nutrient use
- More efficient water-use
- Immunity to disease
- Convert $C_3$ to $C_4$ photosynthesis
- Plant biomass to replace fuels
- …

# Where are the chemistry "grand challenges?"

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# Where are the chemistry "grand challenges?"

- Nitrogen fixation
- More efficient nutrient use
- More efficient water-use
- Immunity to disease, insect and weed pressure
- Sensors to reduce food waste
- Plant biomass to replace fuels
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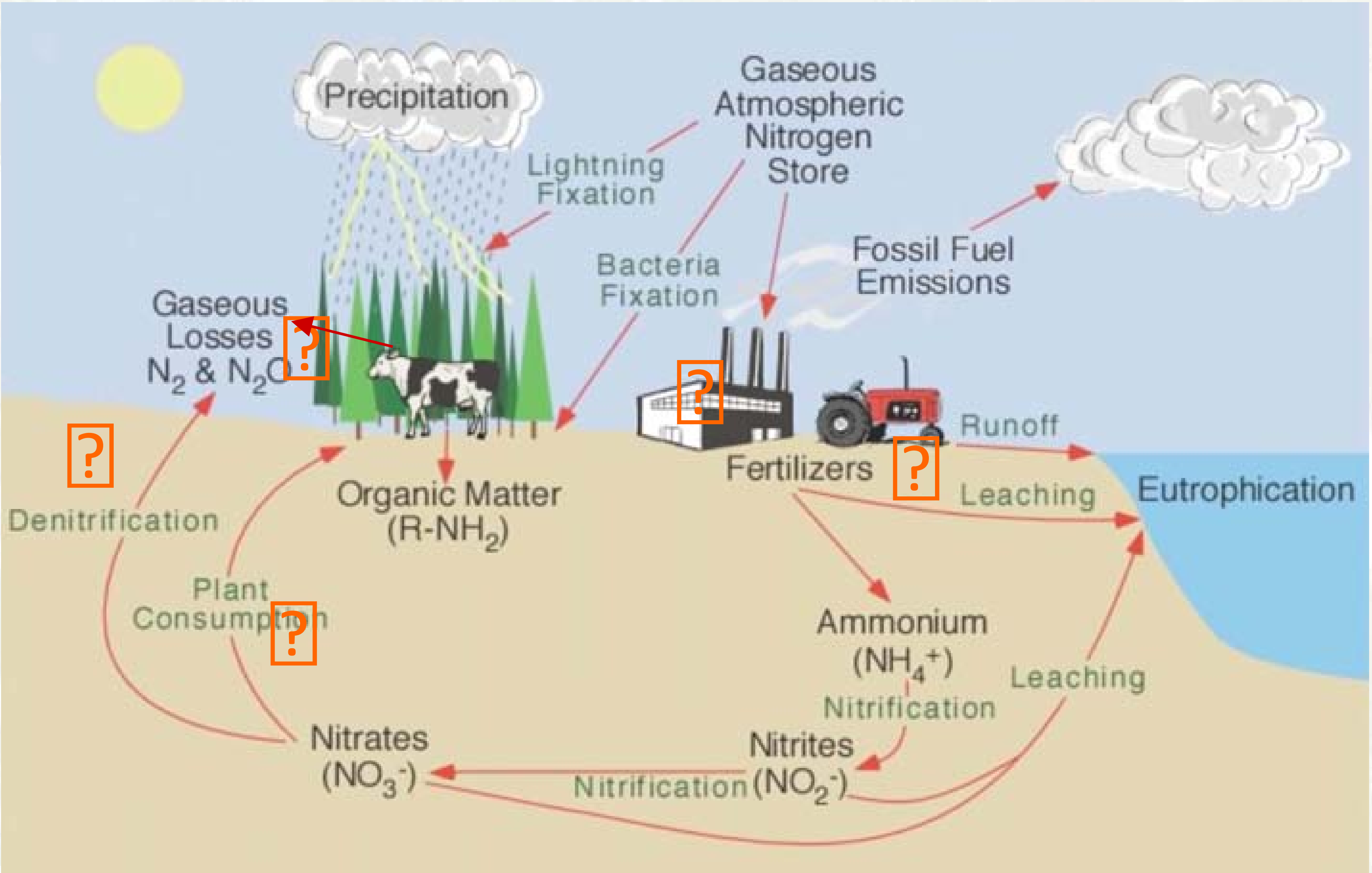
# Reducing nitrogen fertilizer impacts



# Making nitrogen fertilizer use more sustainable

- New catalysts and/or processes
  - energy 250GJ/t N in 1903 reduced to <40 today
  - how much lower is possible?
- New application regimes to reduce losses
  - variable rate application
  - new formulations may be economic as energy costs rise
- De-nitrification inhibitors
- Chemicals to stimulate early root growth

# The phosphate problem

- Absolute requirement for plant growth
- Easily accessible sources close to exhaustion
  - estimates vary from 100-400 years, *i.e.* needs action
- In theory there is plenty, but:
  - no active recycling (BSE stopped bone use)
  - most occurs as low abundance minerals
  - behaviour in soil very poorly understood

# The need to develop soil science

- Soil remains poorly understood
  - macro- and micro-heterogeneous
  - solid state
  - spatial analysis vital, but hard to do non-disruptively
- Lack of understanding limits:
  - carbon capture strategies
  - optimisation of nitrogen and phosphorus applications
  - optimisation of rhizosphere for sustainable productivity
  - targeted delivery of effect chemicals

# Cruiser stimulates early root growth


- Vigorous crop establishment
- Increased efficiency of nutrient uptake

# Biological *v.* chemical N fixation

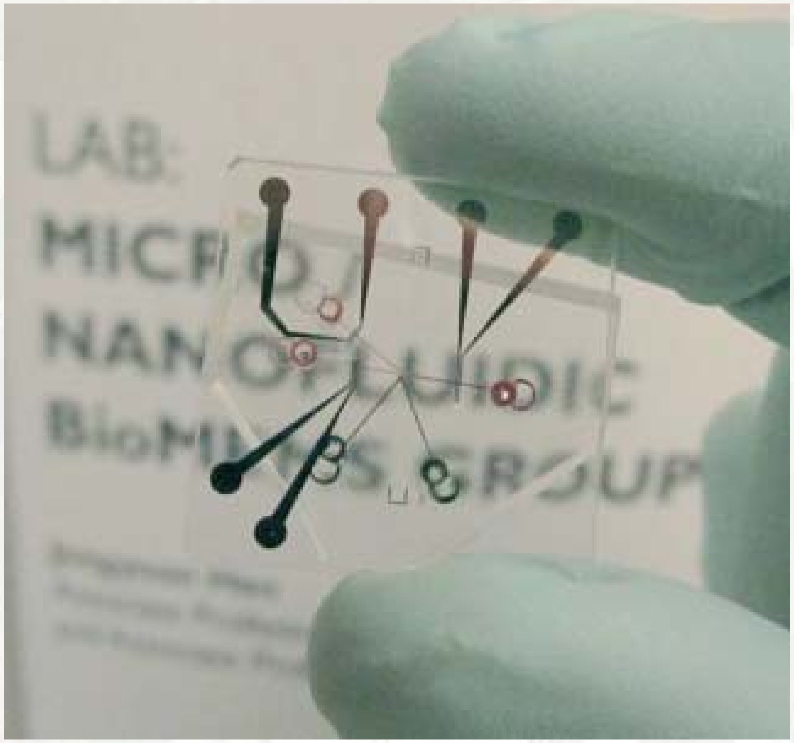
- Biological
  - N-fixation in more crops
  - many genes need moving
  - GM crop
  - 20-40% yield loss *via* swap of C- for N-fixation
  - more land needed
  - more energy in cultivation
- Chemical
  - Renewable energy
  - nano-catalysts
  - optimised process
  - reduced losses through application and formulation
  - treated plants to increase uptake
  - inhibition of denitrification

# Chemical approaches to water sustainability

- Lower energy processes for desalination
- Sensors for on-demand irrigation
- Chemicals to improve tolerance to drought stress

# Nanotechnology for low energy desalination

- Ion concentration polarization zone generated in a microfluidic channel
- Removes salts from seawater
- Improved energy efficiency




Han et al, Nature Nanotechnology March 2010
http://www.nanowerk.com/spotlight/spotid=15433.php

# Crop Enhancement chemicals for water efficiency

- Programme containing Growth regulator “Moddus” in Wheat
- Yield +15-25%; Reduced irrigation - Water savings 15%
- “Crop per Drop” improvement ca 35%

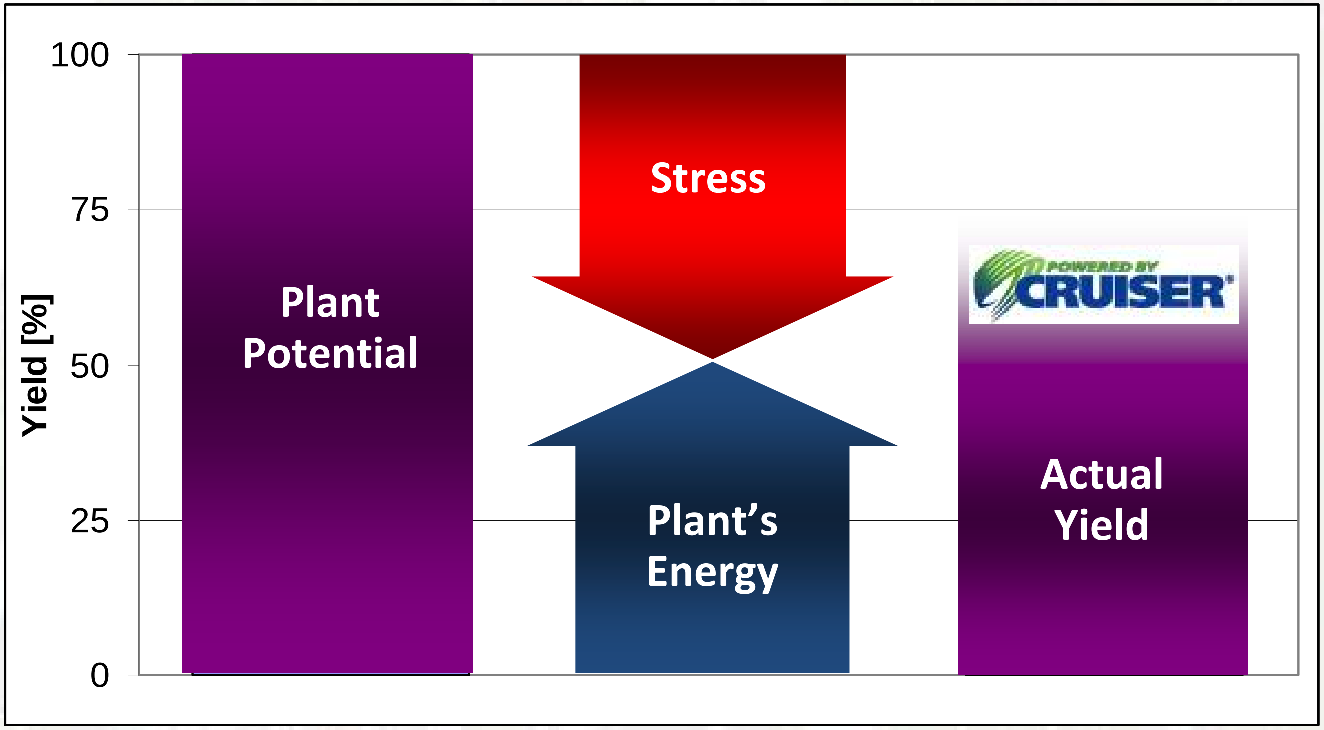
# Ongoing need for new AI’s

- Resistance management for F/H/I
  - complement genetic approaches
  - new herbicide moa urgently needed
  - evolving range of species
- Higher regulatory hurdles
  - may mean combining sub-optimal controls, more ST
- Chemical crop enhancement
  - can new ‘omic tools enable targeted discovery?

***Improving drug design is a key grand challenge in pharma also***

# Seed treatment: chemicals complement genetics

Abiotic stresses are responsible for more than 50% yield reduction.
Thiamethoxam shown to activate proteins that protect against stress.



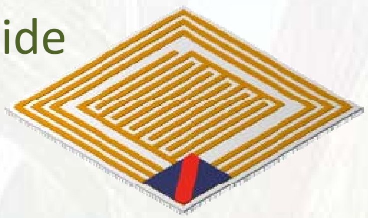

Stress: drought, heat, salinity, UV light, nutrient deficiency etc.

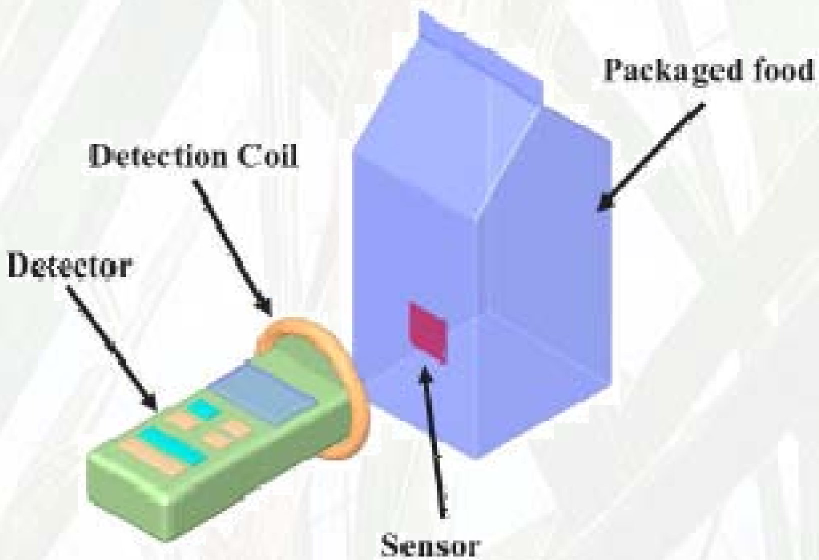
# Sensors to reduce food waste

- Precautionary wastage of food up to 25%
  - over-interpretation of “best before” dates
  - lack of education has reduced consumer discretion
- Many food emit volatiles when “turning”
  - chemical or microbial degradation
- Challenge to develop cheap, specific sensors
  - pence per sensor
  - different sensors for different food type

# Examples: moisture content & fruit ripening

RFID moisture sensor inside pack






scanned in storage or store


sensor changes colour with ripeness

# Chemistry can help to feed the world

- Catalysis
  - beating activation energy
- Formulation
  - beating competing pathways for targeted, timed delivery
- Separation
  - beating entropy
- New effectors
  - beating resistance, regulatory standards, plant stresses
- Sensors
  - beating wastage of still wholesome food