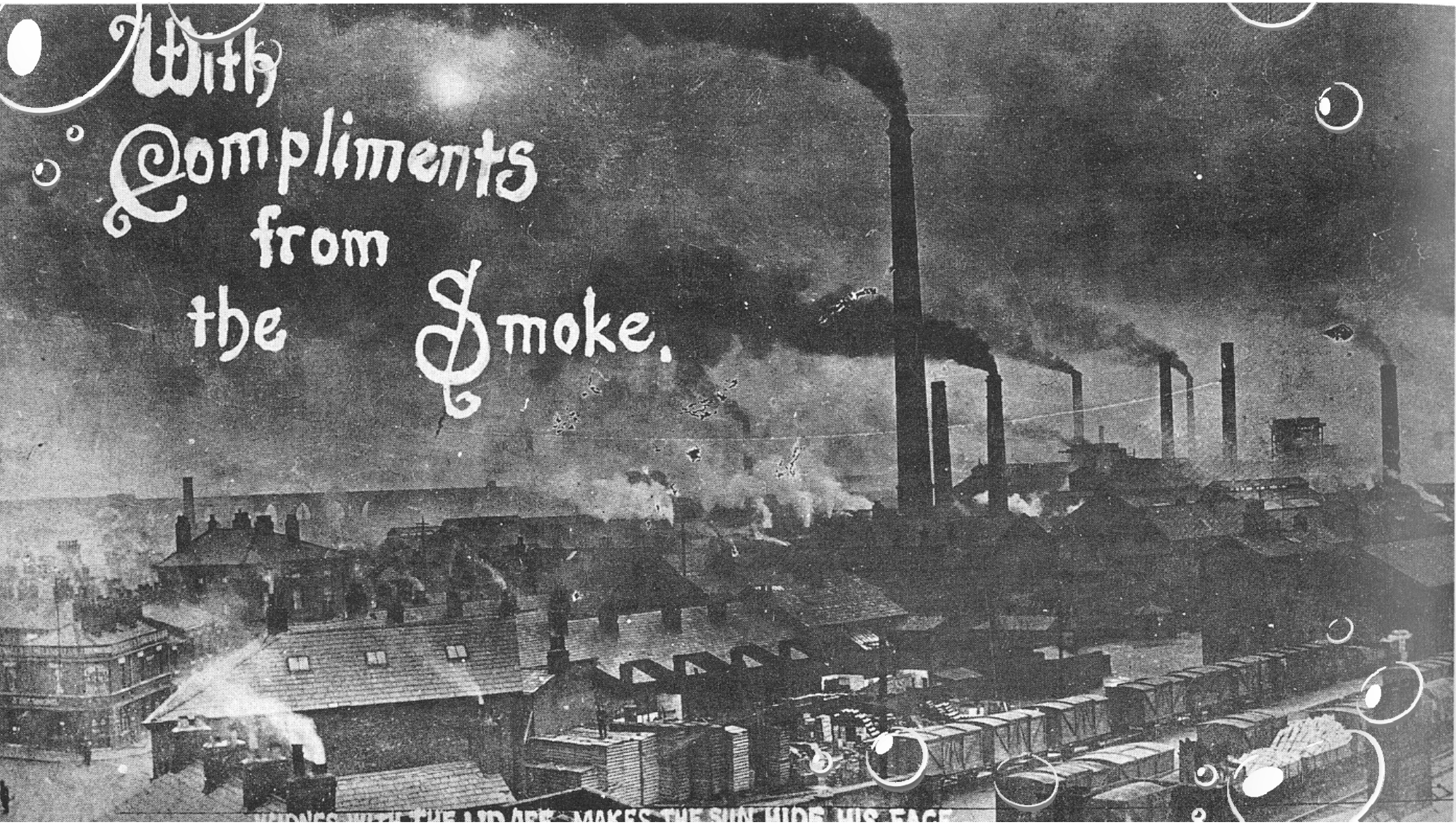
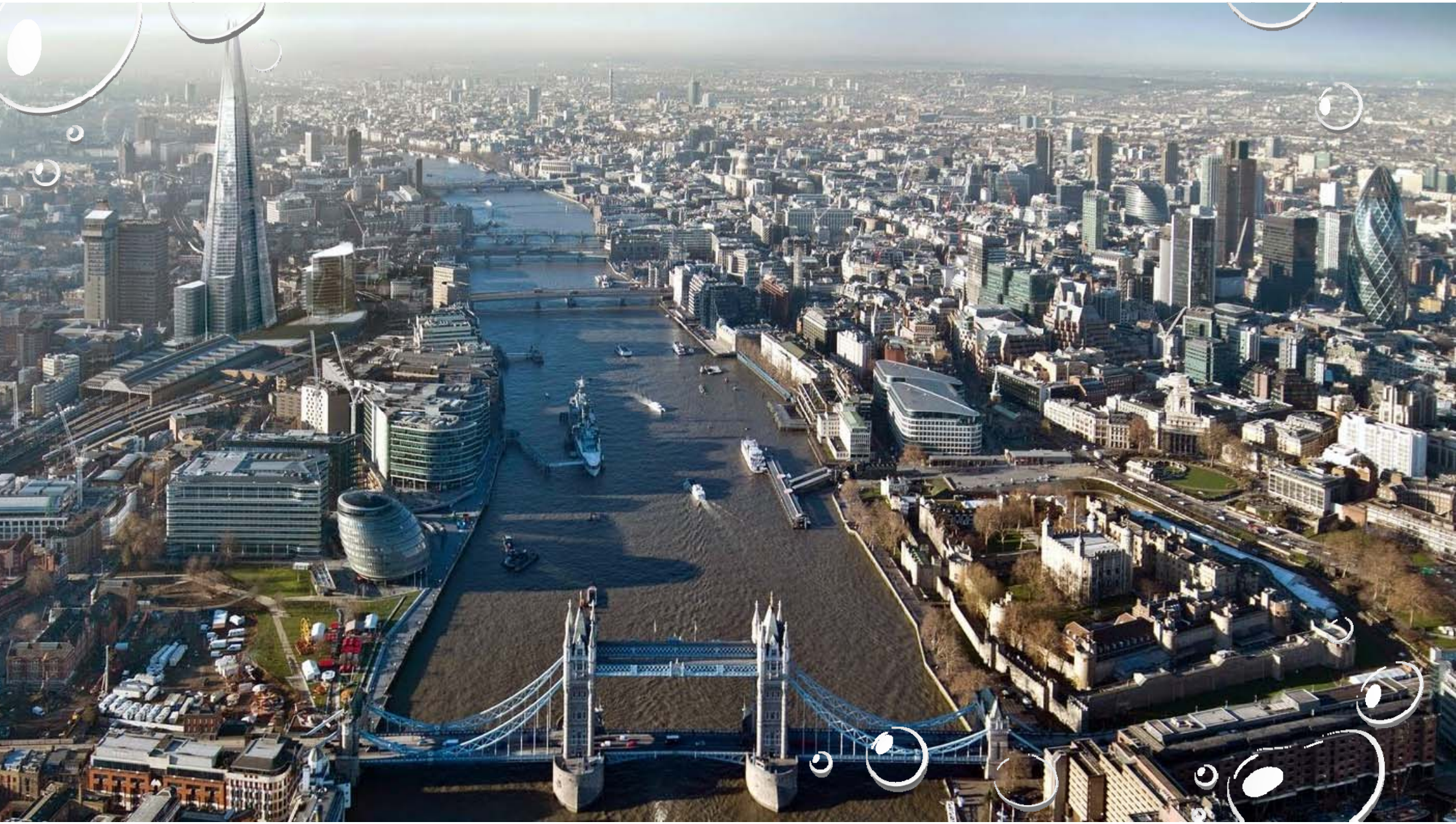
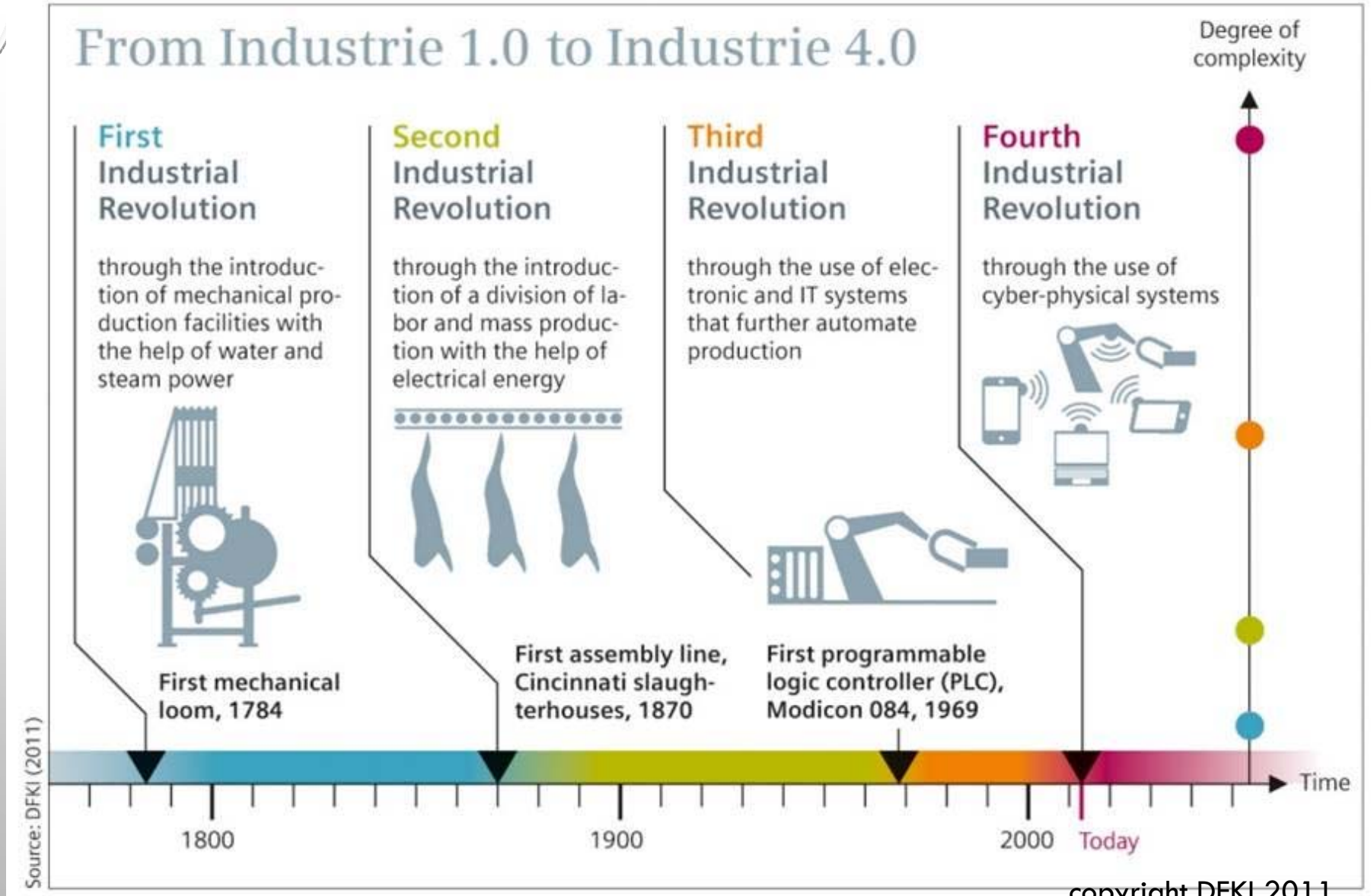
# HOW TO 'DIAL-A-MOLECULE'

Prof. Mimi Hii, Imperial College London
co-I, DaM phase III

Dial-a-Molecule annual meeting, Liverpool, 21 June 2017


With Compliments from the Smoke.





# How about Chemistry?

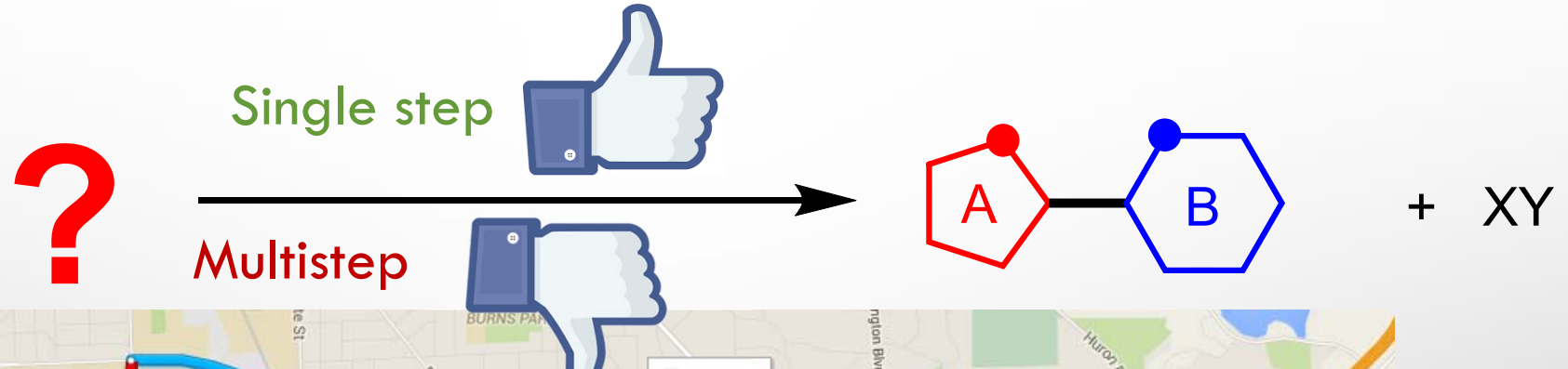
Joseph Wright of Derby
"The Alchemist discovering Phosphorus" (1771)

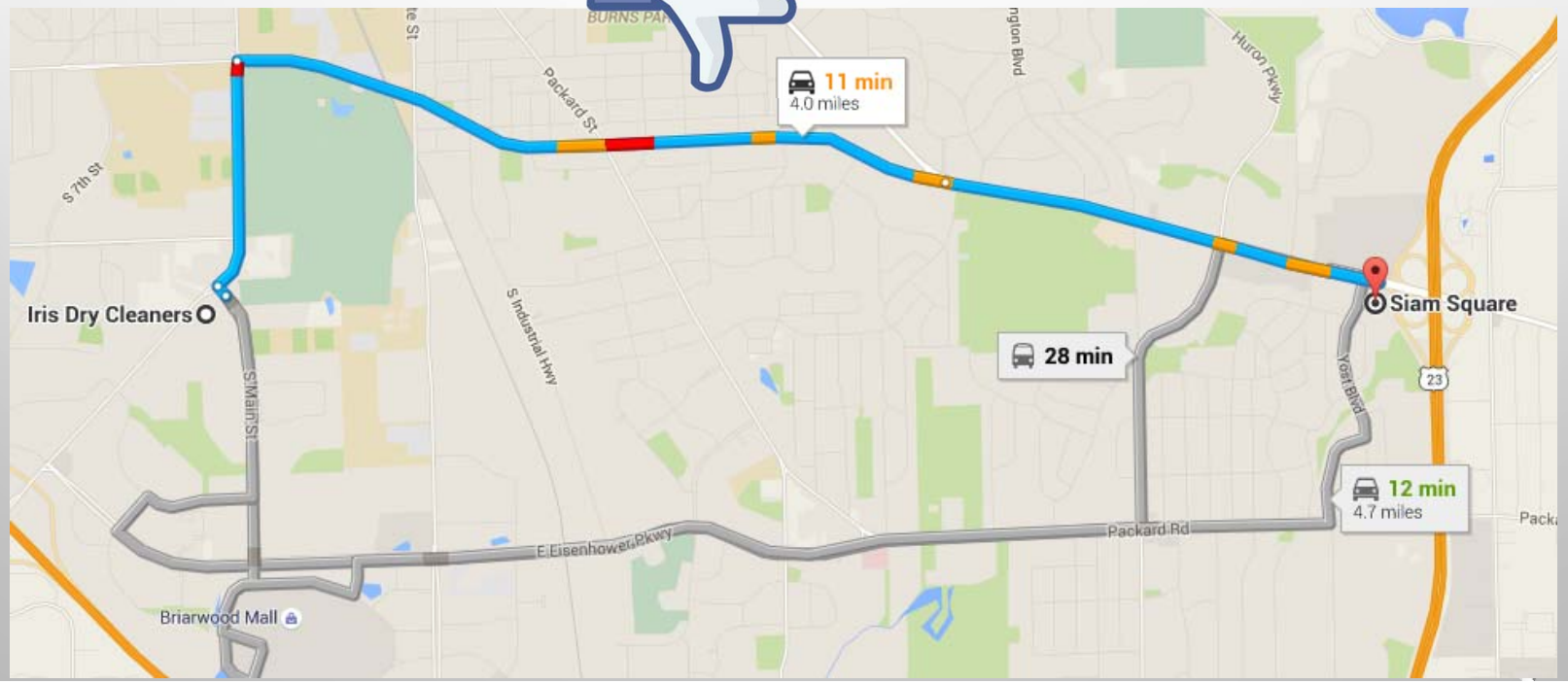
A modern day rotary evaporator…

GeneVac (parallel evaporator)

# HOW TO MAKE A MOLECULE?

## Reduce derivatives (Step-economy)

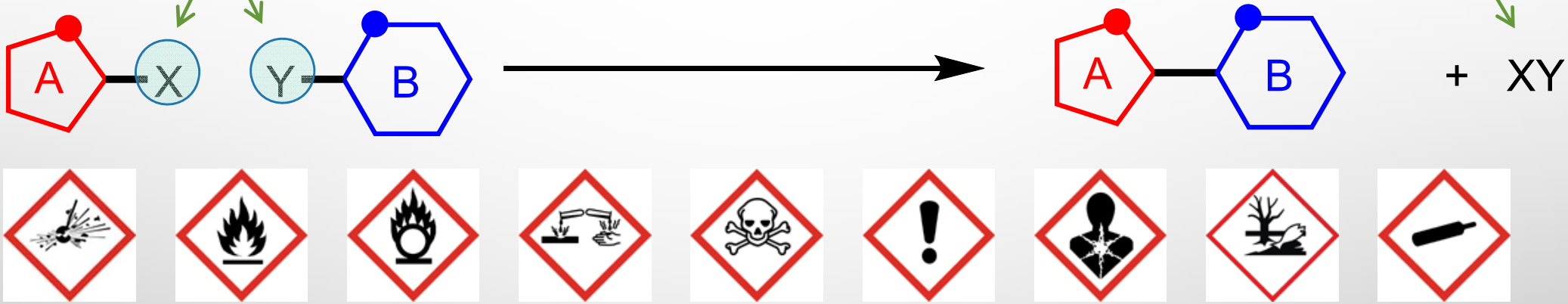


# HOW TO MAKE A MOLECULE?

Atom economy

Prevention




**Less Hazardous** Chemical Synthesis

**Designing safer** chemicals

**Safer** solvents and auxiliaries

**Design** for degradation

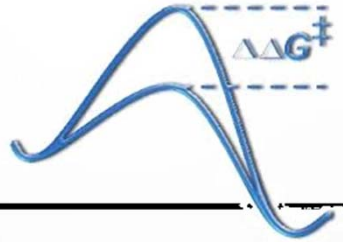
**Inherent safer** chemistry for accident prevention

'12 Principles of Green Chemistry':
P. T. Anastas, J. C. Warner, Green Chemistry: Theory and Practice, Oxford University Press: NY, 1998, p.30.

# HOW TO MAKE A MOLECULE?

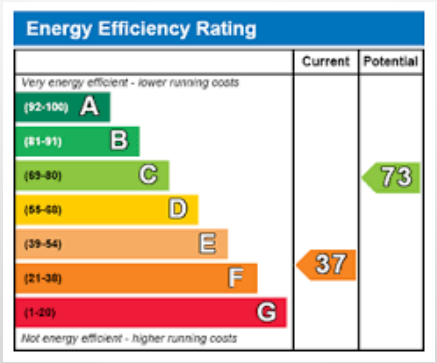

Use of renewable feedstocks

Catalysis



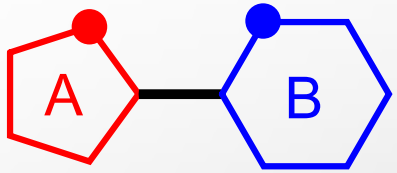

Temperature

Pressure

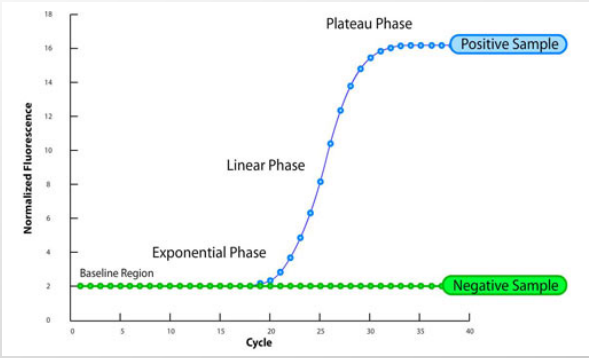



Design for energy efficiency

Real-time analysis (pollution prevention)




+ XY




'12 Principles of Green Chemistry':

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# REACTION VARIABLES (OPTIMISATION)

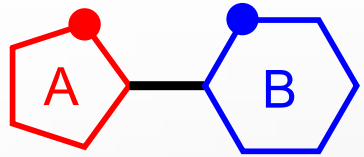

*Catalyst?*

*Solvent(s)?* *Pressure?*

*Time?*

Energy source?

Heat, light, electricity, microwave



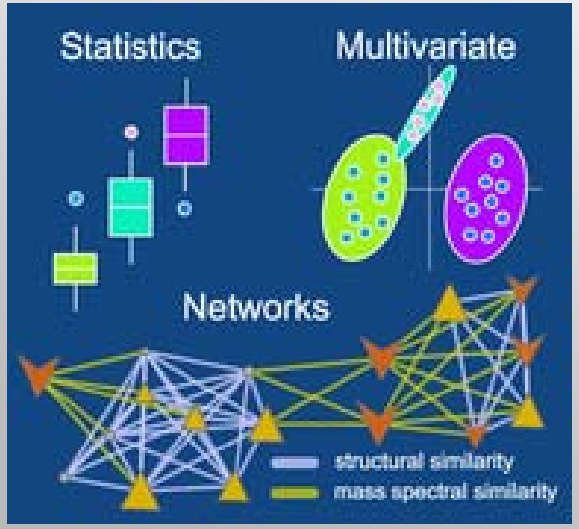

*Product yield* ↑

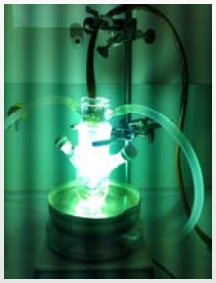
*Waste management*

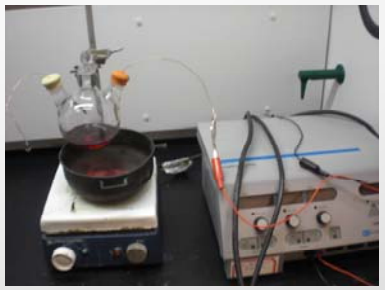
*Reactive centres?*

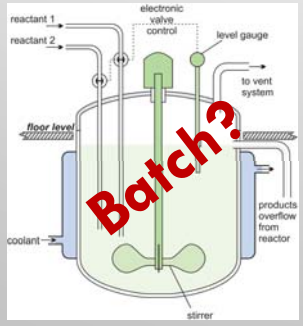
*Physical properties?*

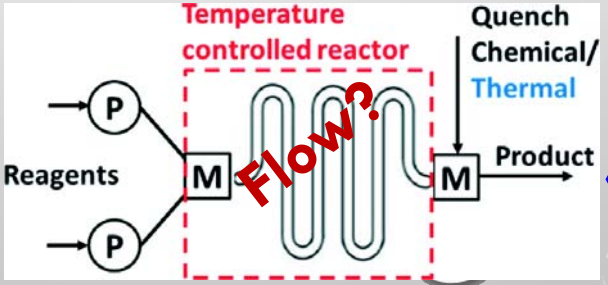
*Potential Hazards?*

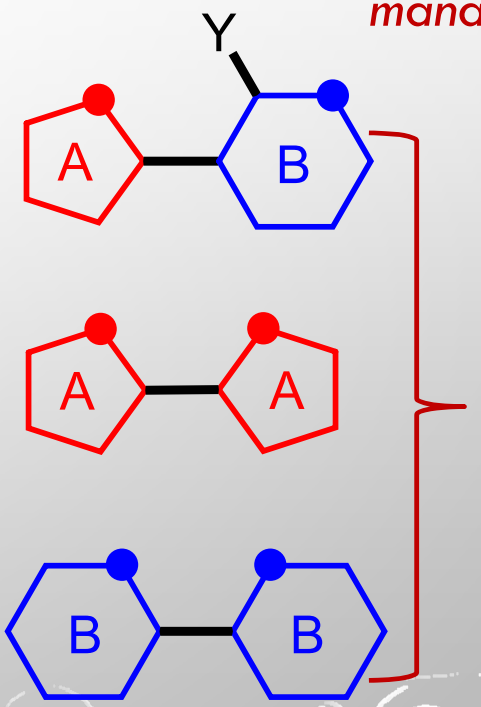






# THE CHALLENGE

**FROM:**

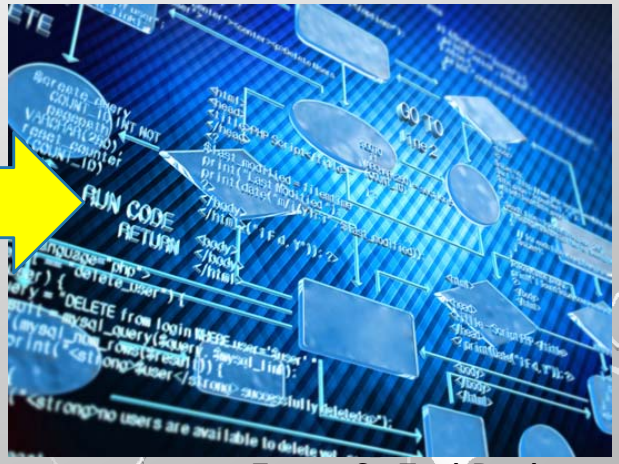
*The Alchemist discovering phosphorus*
Joseph Wright of Derby (1771)

**TO:**


NEW PLATFORM (AUTOMATION)

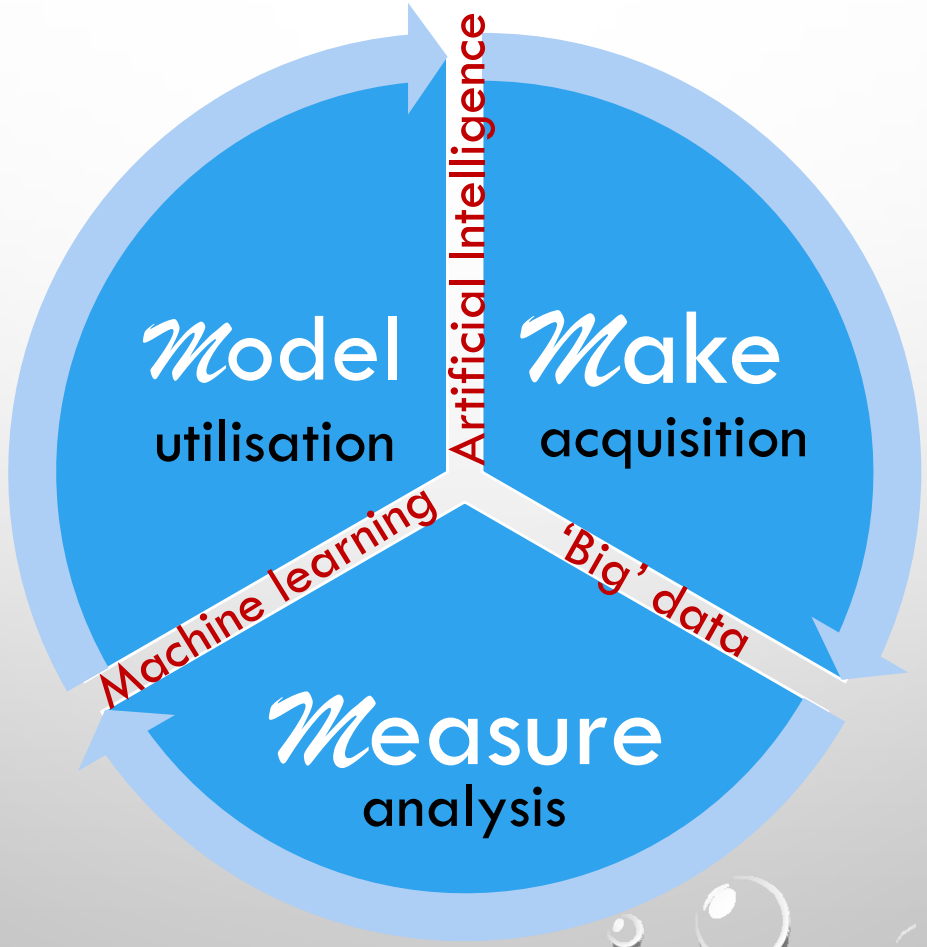

en.wikipedia.org/wiki/Laboratory_robotics

DATA ANALYSIS/PREDICTION




From: SciTechDaily

# WORKFLOW OF AN AUTONOMOUS SYSTEM



# DIAL-A-MOLECULE GRAND CHALLENGE

*How can we molecules in days not years?*

http://generic.wordpress.soton.ac.uk/dial-a-molecule/

Phase I & II: 2010-5 (PI: Richard Whitby; co-I's: Steve Marsden, David Harrowven)
Phase III: 2016-2020 (PI: Richard Whitby; co-I: Mimi Hii)

**Computer-assisted organic synthesis software**: WODCA, Organic Synthesis Exploration Tool (OSET), CHIRON, SynGen, LHASA, SYLVIA, ICSynth, Chematica.

**Computation software**: DFT, Multivariate analysis, kinetic models.

**Quality and quantity of reaction data:** Stepstone group, Open data framework, National reaction database?

**Predictable reaction outcome/success rate**

# DATA ACQUISITION

## Discovery

- Parallel reaction platform(s) up to 96 parallel reactions
- Automatic dispensing, dosing and sampling capability
- LC, GC and MS rapid analysis capability: few data points per reaction

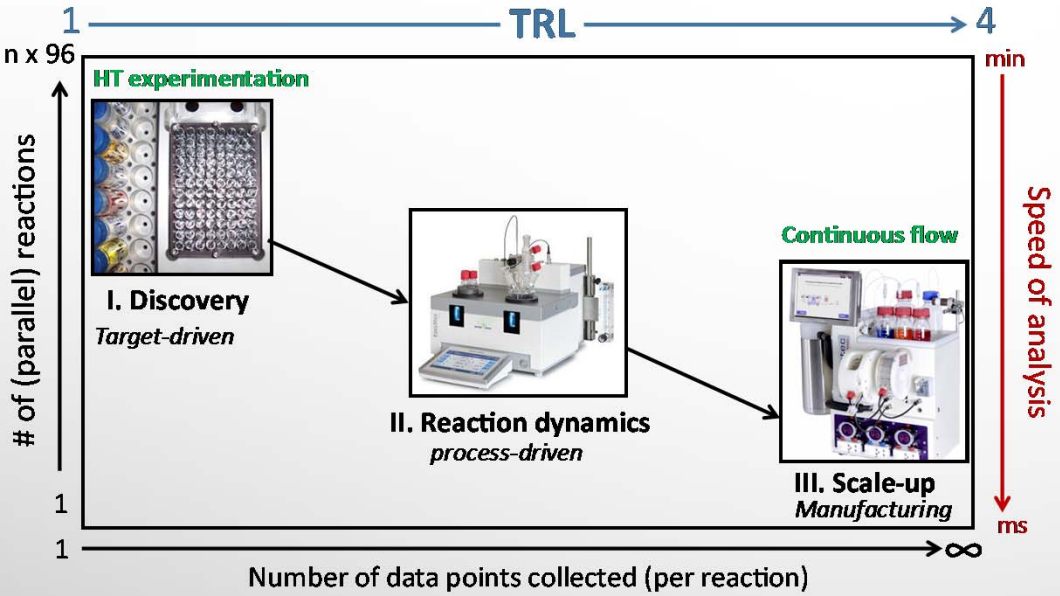
## Reaction Dynamics

- Study of reaction dynamics using spectroscopy, calorimetry, multiple sampling etc to generate high-quality multiple data points per reaction.
- Mono- to multiphasic reactions, including high T/P

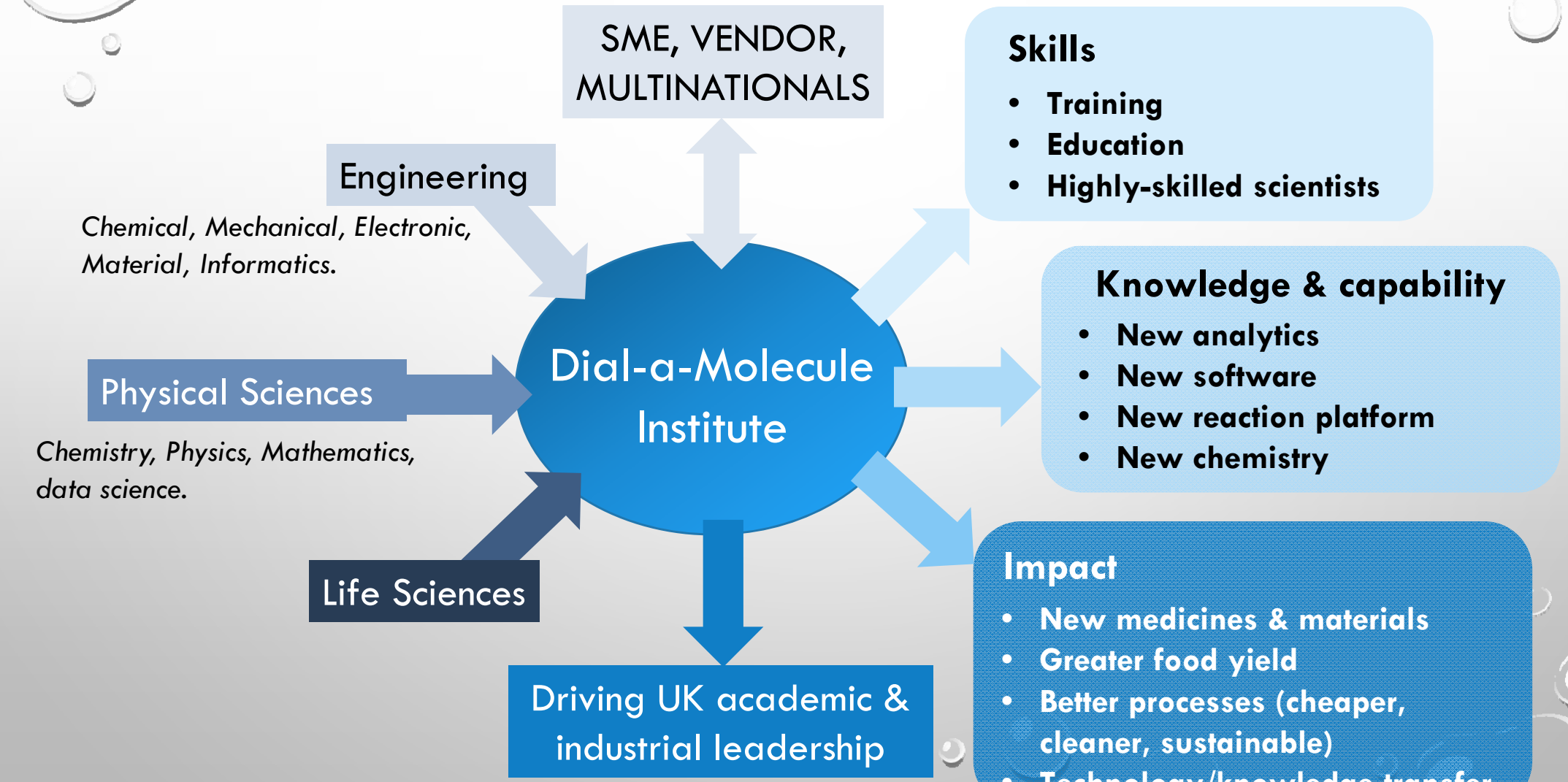
## Continuous Flow

- 'New' reaction platforms, e.g. photochemistry
- Understand process robustness (e.g. catalyst stability), process intensification
- Continuous monitoring (inline/online analytics)

# DIAL-A-MOLECULE GC INSTITUTE: RAPID ONLINE ANALYSIS OF REACTIONS (ROAR)



# THE VISION


SME, VENDOR, MULTINATIONALS
Engineering
Chemical, Mechanical, Electronic, Material, Informatics.
Physical Sciences
Chemistry, Physics, Mathematics, data science.
Life Sciences
Dial-a-Molecule Institute
Driving UK academic & industrial leadership
Skills
• Training
• Education
• Highly-skilled scientists
Knowledge & capability
• New analytics
• New software
• New reaction platform
• New chemistry
Impact
• New medicines & materials
• Greater food yield
• Better processes (cheaper, cleaner, sustainable)
• Technology/knowledge transfer

# COST OF THE PROJECT

| Item | Costs/£ | EPSRC[a]/£ | Imperial[b]/£ | Sponsors[c]/£ |
|---|---|---|---|---|
| Equipment | 2,208,591 | 2,208,591 | - | - |
| Building costs | 875,000 | - | 875,000 | - |
| Personnel | 64,6453 | 418,711 | 216,585 | - |
| Estate & indirect costs | 62,412 | 62,412 | - | - |
| Consumables | 60,000 | 60,000 | - | - |
| Maintenance | 44,142 | 44,142 | - | - |
| Software, licenses | 85,663 | 85,663 | - | - |
| Travel & subsistence | 15,000 | 15,000 | - | - |
| Cash | - | - | 30,000 | 63,000 |
| In kind | - | - | - | 681,079 |
| Total cost(s) | £4,760,183 | 2,894,519 (60.8%) | 1,121,585 (23.6%) | 744,079 (15.6%) |

# STATEMENT OF NEED

**Society:** Synthesis by design, on-demand will have a transformative effect on the future of manufacturing to more localised production based on available resources.

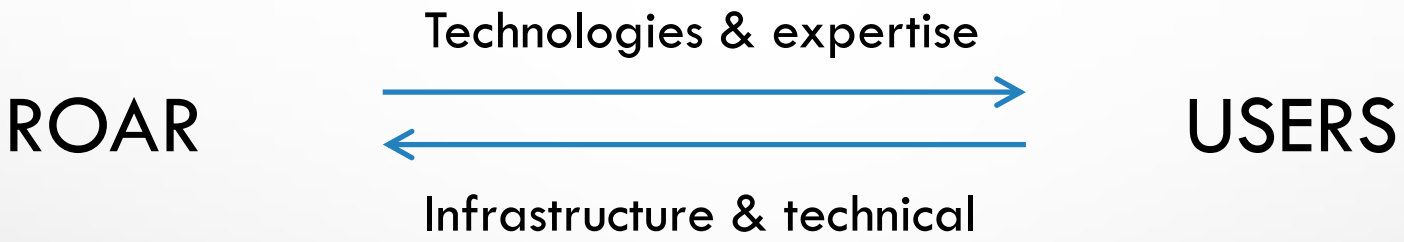
**Academia:** Provide new synthetic tools and technology to advance chemical research (Lab of the future). Training next generation of synthetic chemists. Facilitate collaboration with developers and end-users of these technology.

**CRO, SME:** Resources for capital investment is limited – access to GCI to assess and evaluate the most appropriate technology for their business in order to justify longer term investment. Overall, improve capability and technological advantages over their competitors.

**Vendors:** Develop relevant scientific equipment to the synthetic chemistry community. The GCI will allow them to deliver appropriate training, beta-test and debug prototypes (faster time-to-market). Unbiased endorsement (promote sales).

**Large Internationals:** Ultimate beneficiary of all the above activities – access to highly-skilled work force, supported by more technologically advanced CRO's and SME's. Ability to collaborate more widely with Academia and other industry to develop next generation of reaction platform.

# SUSTAINABILITY




Mechanisms:

1. Paid access (user survey)
2. Research projects supported by DaM network – support for accessing facility in proposals
3. £62/h FEC (TRAC) – reduced to £14/h non-FEC and £59 FEC
4. Non-profit making in years 1-3
5. Charge-out fee structure to be determined by demand
6. Significant demand = future expansion for ROAR/regional 'spokes'

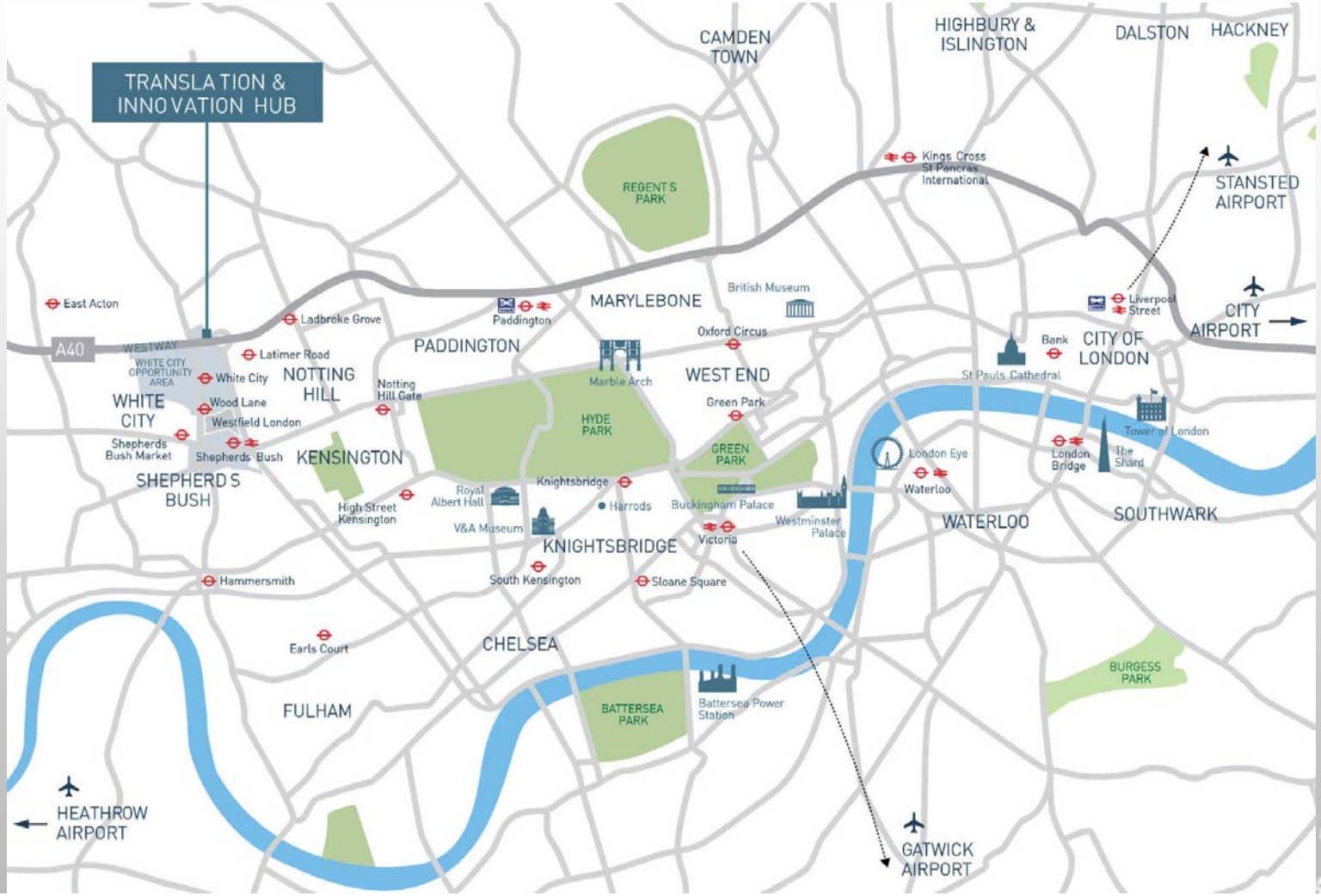
# WHERE?

- Molecular Sciences Research Hub, White City Campus.
- Scheduled to open 2018.

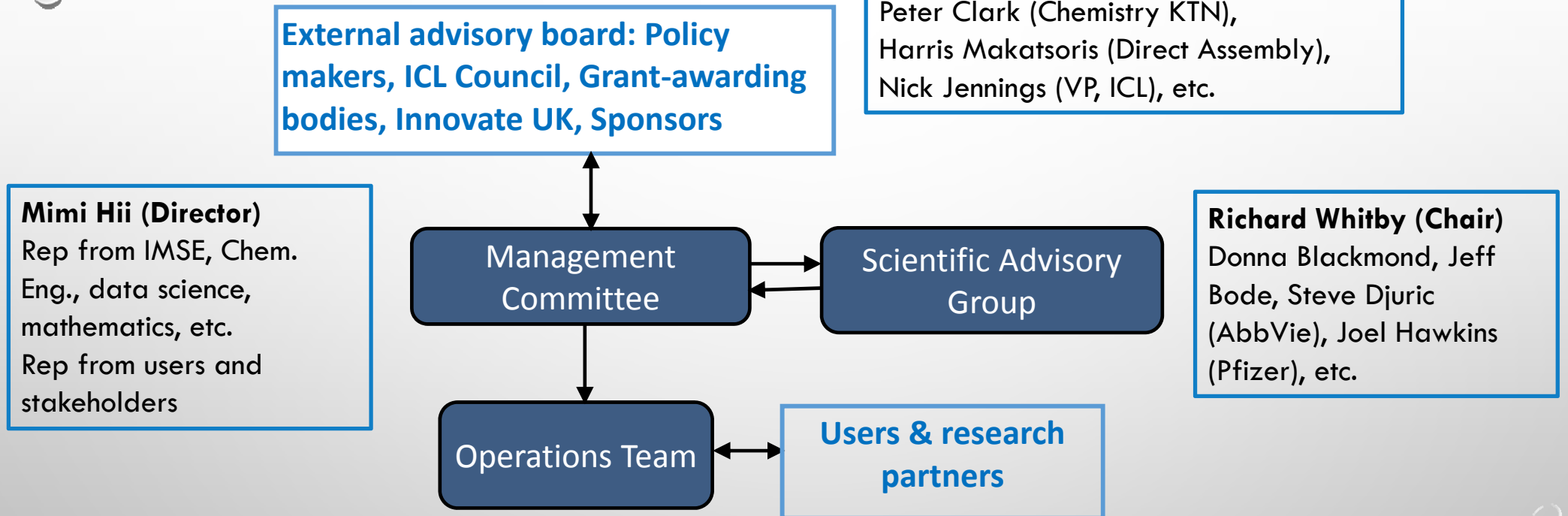
*'…drive a new way of doing chemistry that **transcends disciplinary and institutional boundaries** in the search for solutions to some of the great challenges facing humanity.'*

https://www.imperial.ac.uk/white-city-campus/

# LOCATION


TRANSLATION & INNOVATION HUB
CAMDEN TOWN
HIGHBURY & ISLINGTON
DALSTON
HACKNEY
REGENT'S PARK
Kings Cross St Pancras International
STANSTED AIRPORT
East Acton
A40
WESTWAY
WHITE CITY OPPORTUNITY AREA
Ladbroke Grove
Latimer Road
White City
Wood Lane
Westfield London
Shepherds Bush Market
Shepherds Bush
WHITE CITY
SHEPHERD'S BUSH
NOTTING HILL
Notting Hill Gate
KENSINGTON
High Street Kensington
Paddington
PADDINGTON
MARYLEBONE
British Museum
Oxford Circus
Marble Arch
WEST END
HYDE PARK
Green Park
GREEN PARK
Knightsbridge
Harrods
Buckingham Palace
Royal Albert Hall
V&A Museum
KNIGHTSBRIDGE
Victoria
Westminster Palace
South Kensington
Sloane Square
Hammersmith
Earls Court
CHELSEA
FULHAM
BATTERSEA PARK
Battersea Power Station
Liverpool Street
CITY AIRPORT
Bank
CITY OF LONDON
St Pauls Cathedral
Tower of London
London Eye
London Bridge
The Shard
Waterloo
WATERLOO
SOUTHWARK
BURGESS PARK
HEATHROW AIRPORT
GATWICK AIRPORT

# GOVERNANCE


External advisory board: Policy makers, ICL Council, Grant-awarding bodies, Innovate UK, Sponsors
Peter Clark (Chemistry KTN), Harris Makatsoris (Direct Assembly), Nick Jennings (VP, ICL), etc.
Mimi Hii (Director)
Rep from IMSE, Chem. Eng., data science, mathematics, etc.
Rep from users and stakeholders
Management Committee
Scientific Advisory Group
Richard Whitby (Chair)
Donna Blackmond, Jeff Bode, Steve Djuric (AbbVie), Joel Hawkins (Pfizer), etc.
Operations Team
Users & research partners
Ben Deadman (Facility Manager)
2 Technicians + Apprentices
New academics
Instrument vendors (MT, Agilent, etc.)
Academic: Cambridge, Catalysis CDT, Leeds, Manchester, Strathclyde (CPAC)
SME and CRO, including Dr Reddy

# TIME LINE

- Expression of interest (1 December 2016)
- Invitation to submit full proposal (early Feb 2017)
- Submission of full proposal:
  - 10 March (internal approval), 16 March (EPSRC deadline)
- Postal reviews
- Panel interview: 12 July 2017
- Notification: ‘late July’
- Project commence: 1 October 2017
- Move to MSRH: Early 2018

So watch this space……