Introduction

Martin J. T. Milton

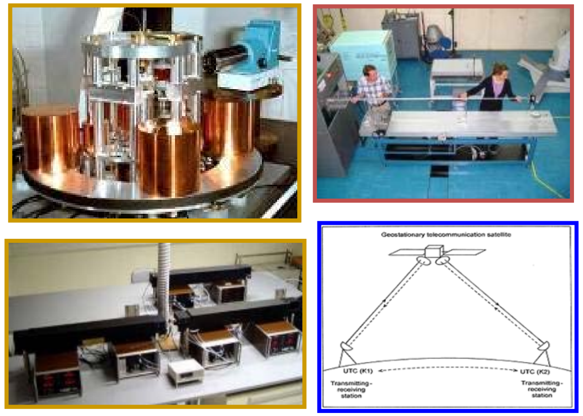
Director of the BIPM

Monday 27th June 2016

Bureau
International des
Poids et
Mesures

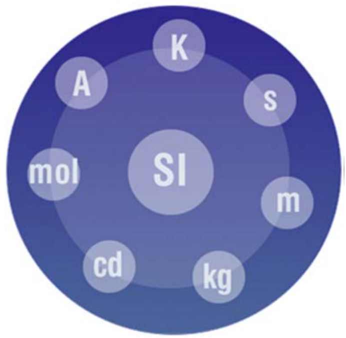
Bureau International des Poids et Mesures

- Established in 1875 by the Metre Convention
- Based in Paris and financed by
  57 Member States and 40 Associate States/Economies.



- **Our mission is to ensure and promote the global comparability of measurements.**
- This is achieved both through technical activities in our laboratories and through international coordination.

- Operate laboratories in: mass, time, electricity, ionizing radiation and chemistry.
- An international staff of around 75 with budget of approximately 12 million euros (for 2012).



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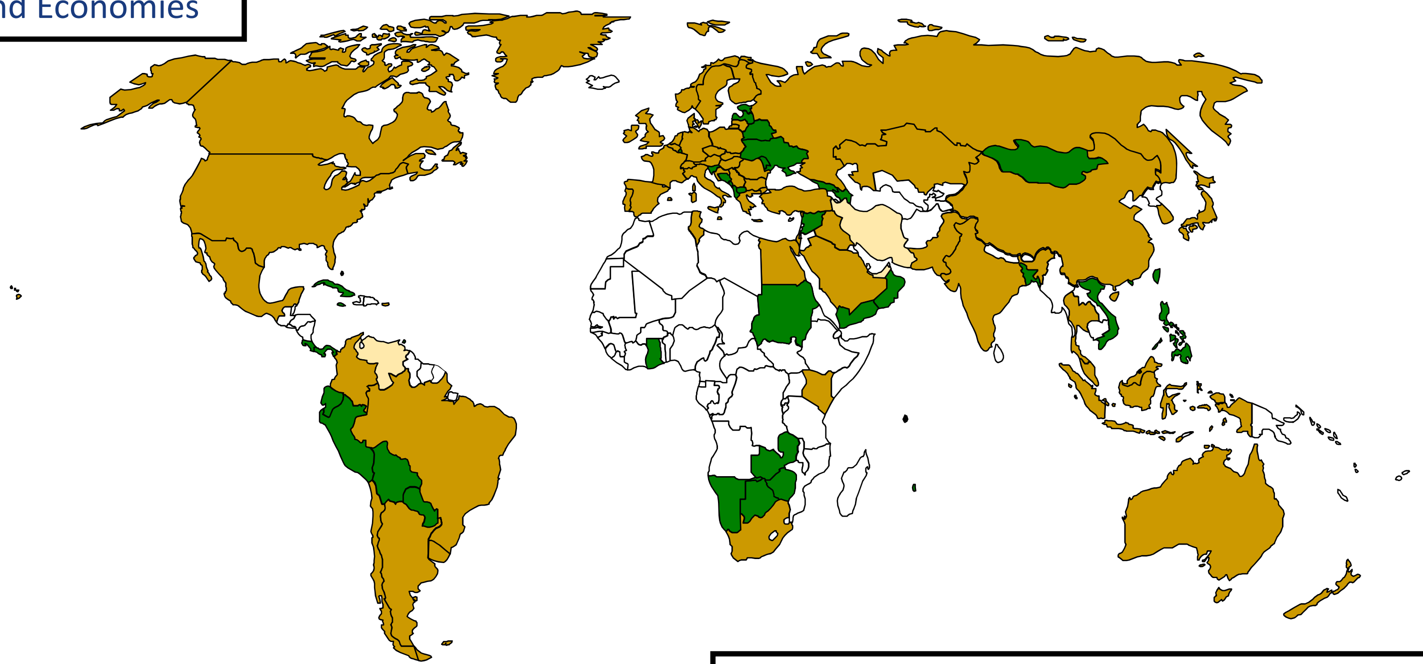
The Member States and Associates of the BIPM

The BIPM

57 Member States

40 Associates and Economies



- Member participating in the CIPM MRA
- Associate participating in the CIPM MRA
- Members/Associates not yet signed the CIPM MRA

The CIPM MRA has been signed by

98 National Metrology Institutes (from 54 Member States, 40 Associates & Economies, 4 international organizations)

plus 153 Designated Institutes = **251 Institutes**

Bureau International des Poids et Mesures

The International System of Units (SI)

Table 5. SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	µ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

Prefixes

Base units

Table 1. SI base units

Base quantity		SI base unit	
Name	Symbol	Name	Symbol
length	*l, x, r*, etc.	metre	m
mass	*m*	kilogram	kg
time, duration	*t*	second	s
electric current	*I, i*	ampere	A
thermodynamic temperature	*T*	kelvin	K
amount of substance	*n*	mole	mol
luminous intensity	I_v	candela	cd

Derived units

Table 3. Coherent derived units in the SI with special names and symbols

	SI coherent derived unit [(a)]			
Derived quantity	Name	Symbol	Expressed in terms of other SI units	Expressed in terms of SI base units
plane angle	radian [(b)]	rad	1 [(b)]	m/m
solid angle	steradian [(b)]	sr [(c)]	1 [(b)]	m^2/m^2
frequency	hertz [(d)]	Hz		s^{-1}
force	newton	N		$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1}\ kg\ s^{-2}$
energy, work, amount of heat	joule	J	N m	$m^2\ kg\ s^{-2}$
power, radiant flux	watt	W	J/s	$m^2\ kg\ s^{-3}$
electric charge, amount of electricity	coulomb	C		s A
electric potential difference, electromotive force	volt	V	W/A	$m^2\ kg\ s^{-3}\ A^{-1}$
capacitance	farad	F	C/V	$m^{-2}\ kg^{-1}\ s^4\ A^2$
electric resistance	ohm	Ω	V/A	$m^2\ kg\ s^{-3}\ A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2}\ kg^{-1}\ s^3\ A^2$
magnetic flux	weber	Wb	V s	$m^2\ kg\ s^{-2}\ A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg\ s^{-2}\ A^{-1}$
inductance	henry	H	Wb/A	$m^2\ kg\ s^{-2}\ A^{-2}$
Celsius temperature	degree Celsius [(e)]	°C		K
luminous flux	lumen	lm	cd sr [(c)]	cd
illuminance	lux	lx	lm/m^2	m^{-2} cd
activity referred to a radionuclide [(f)]	becquerel [(d)]	Bq		s^{-1}
absorbed dose, specific energy (imparted), kerma	gray	Gy	J/kg	$m^2\ s^{-2}$
dose equivalent, ambient dose equivalent, directional dose equivalent, personal dose equivalent	sievert [(g)]	Sv	J/kg	$m^2\ s^{-2}$
catalytic activity	katal	kat		s^{-1} mol

The 8th edition of the SI Brochure is available from the BIPM website.

The Varenna Metrology Summer School 2016

Metrology for Quality of Life
11 lectures, Mon - Wed

- Chemistry and biology,
- Climate and environmental studies

- *Ionising radiation*
- *Acoustics, ultrasound and vibration.*

Physical Metrology and Fundamental Constants
12 lectures, Mon - Wed

- Electricity and magnetism,
- Mass + related quantities,
- Time,
- Length,
- Temperature,
- Photometry and Radiometry

Fundamentals of Metrology
13 lectures, Thurs - Sat

- Units,
- Measurement uncertainty,
- Quantum metrology,
- Global comparability of measurement.

New challenges for metrology in chemistry (and biology)

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This talk

New challenges for metrology in chemistry (and biology)

– Why are we talking about chemistry and biology?

– How are the challenges different (to physical metrology)?

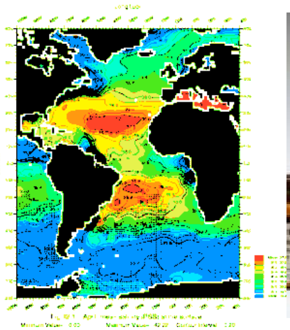
– What about traceability – is it possible?

Why are we talking about chemistry (and biology)?

- They are driven by and contribute to "grand challenges" of global importance:
  - Food, water, air, climate, biodiversity, health …

- They also contribute to very substantial industries with substantial growth and significant potential for innovation:
  - Biotechnology, healthcare, pharmaceuticals …

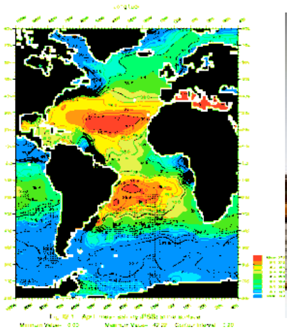
- (Physical measurements also contribute – but in a different way).

Why are we talking about chemistry (and biology)?

- The scope of possible requirements is enormous
  - A highly strategic approach is needed.
  - Some measurands are defined by the method.

- There is only very limited infrastructure in place worldwide
  - Chains of traceability are short
  - Dissemination is largely by distribution of (certified) reference materials
  - Progress will depend on new partnerships

Introducing the objectives of metrology

Measurements that are stable

- The same measurement repeated later gives he same result.

Measurements that are comparable

- Results from different laboratories can be brought together.

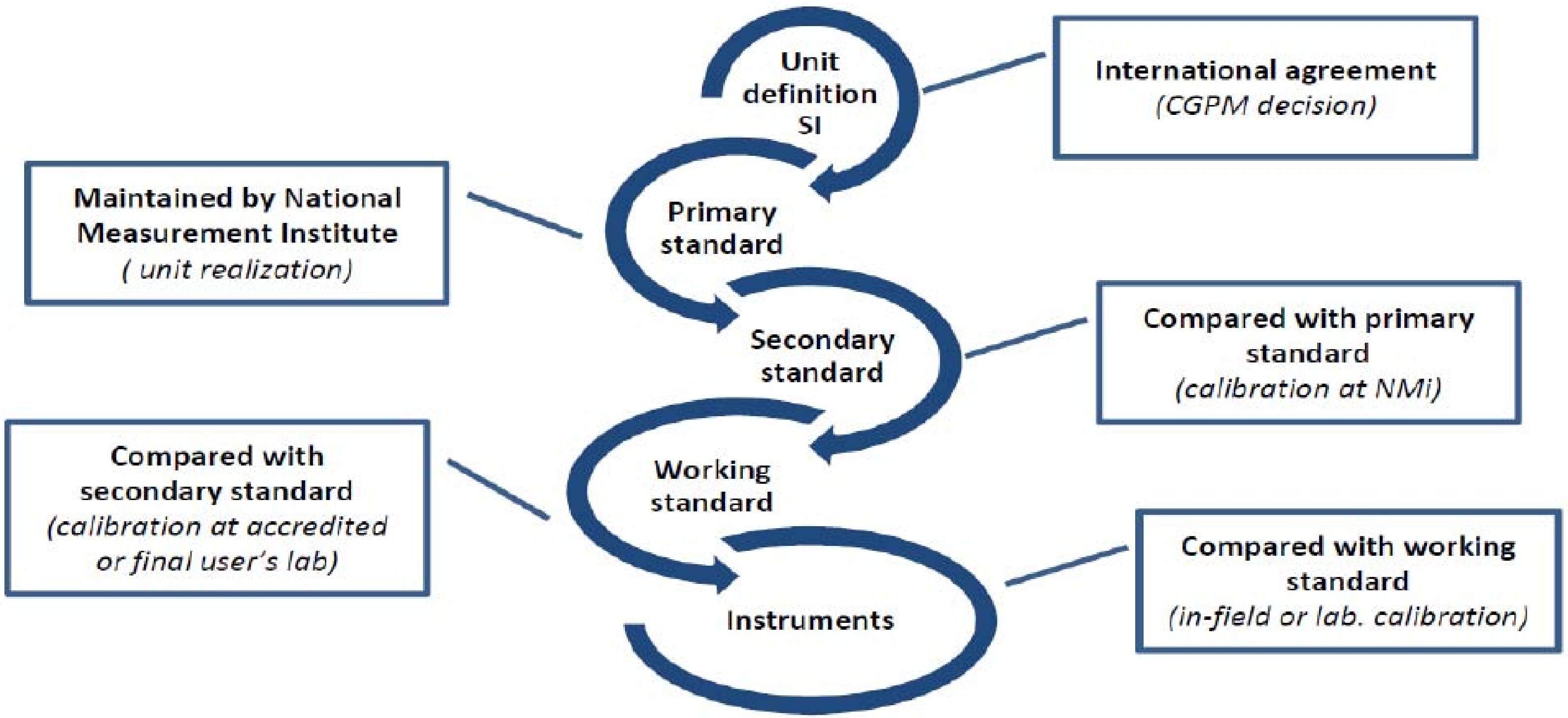
Measurements that are coherent

- Results from different methods can be brought together.

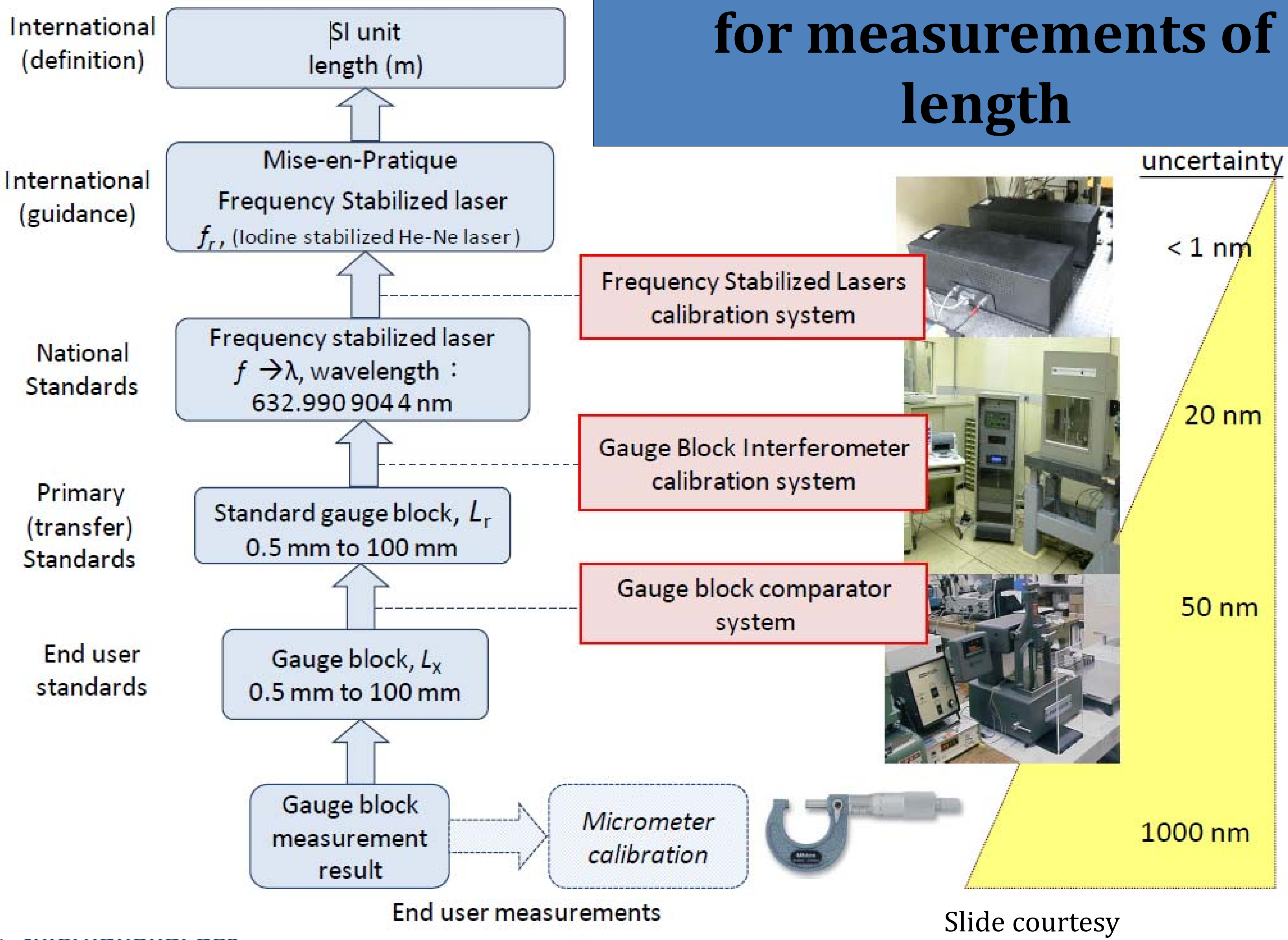
These are achieved through providing the infrastructure to support traceable measurement results (and uncertainties).

"Are these necessary for chemistry (and biology)?"

The traceability "chain"

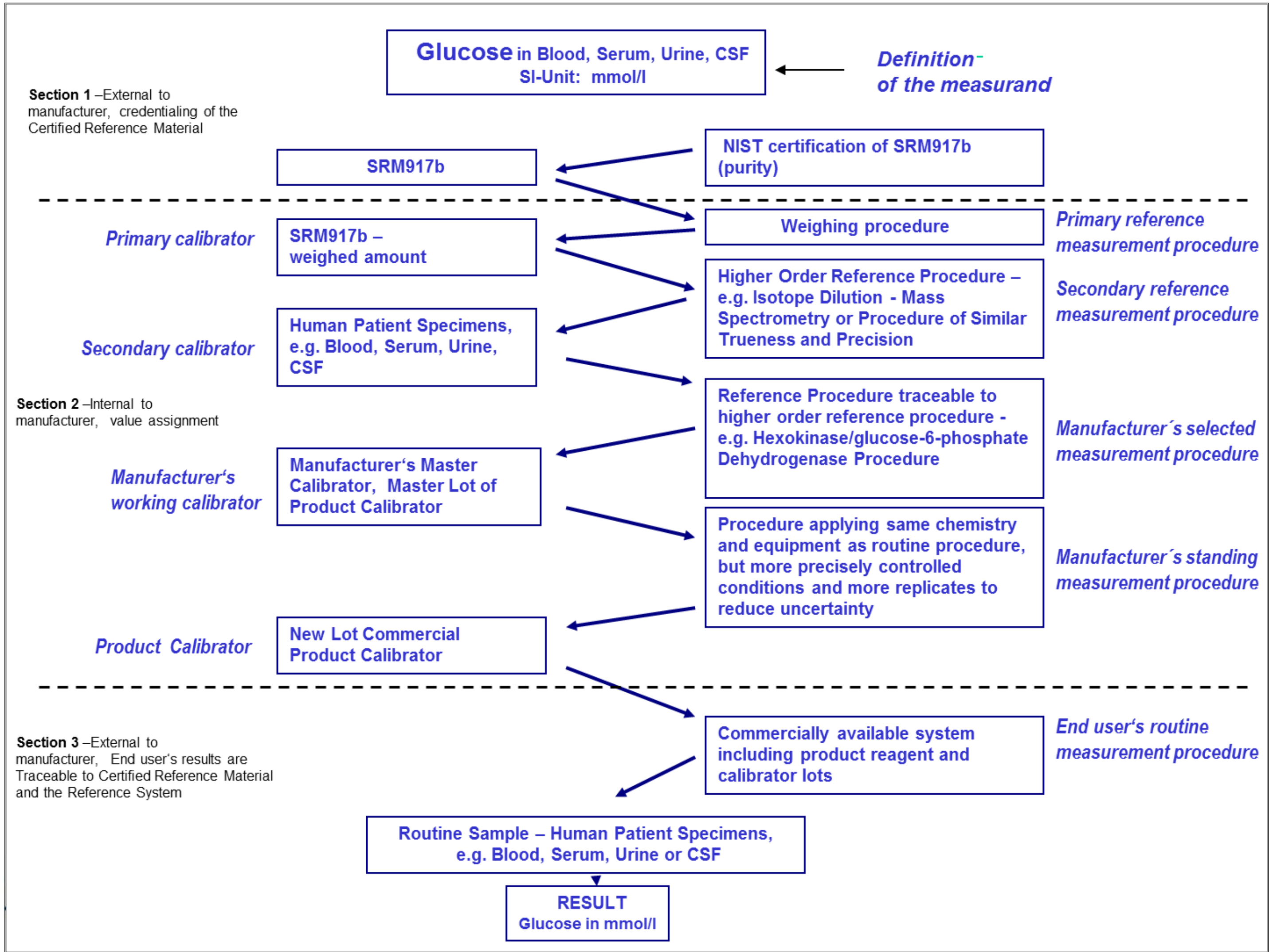


A traceability chain for measurements of length



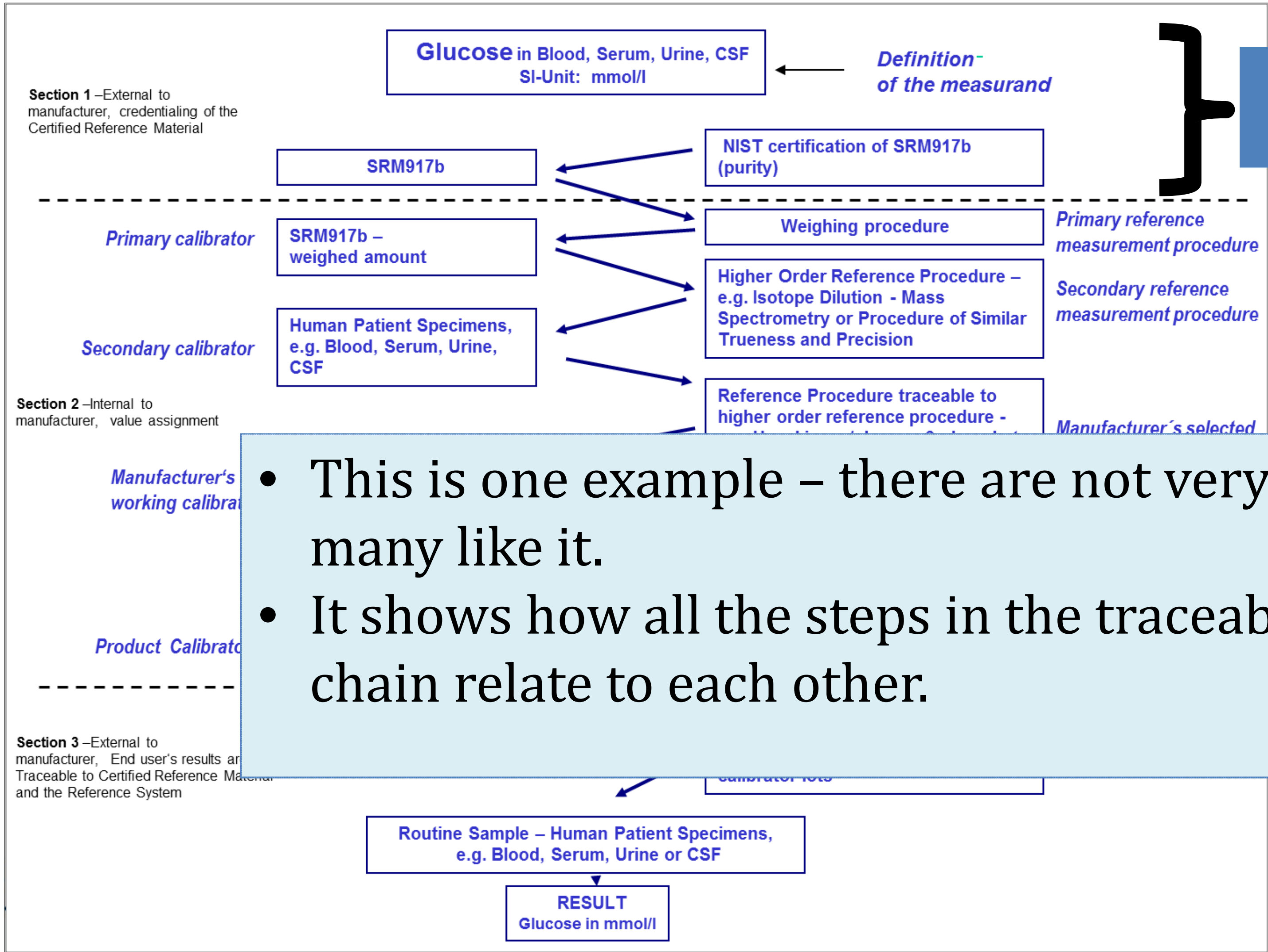
Slide courtesy
Dr S Davidson, NPL, UK

Traceability Chain for the Measurement of Glucose in Body Fluids



Mesures

Traceability Chain for the Measurement of Glucose in Body Fluids

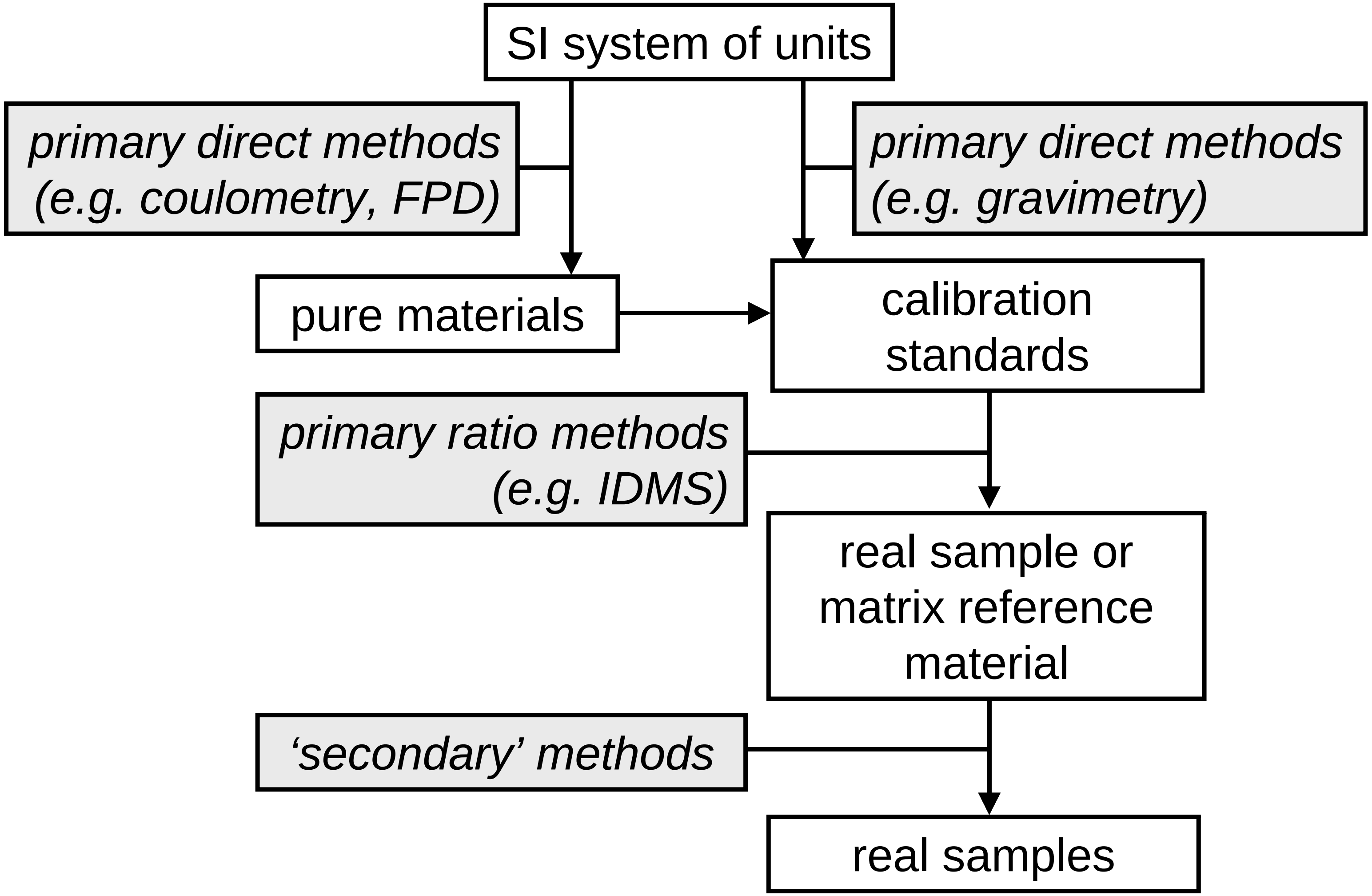


The work of the NMIs

- This is one example – there are not very many like it.
- It shows how all the steps in the traceability chain relate to each other.

Mesures

A general traceability scheme for chemical measurements



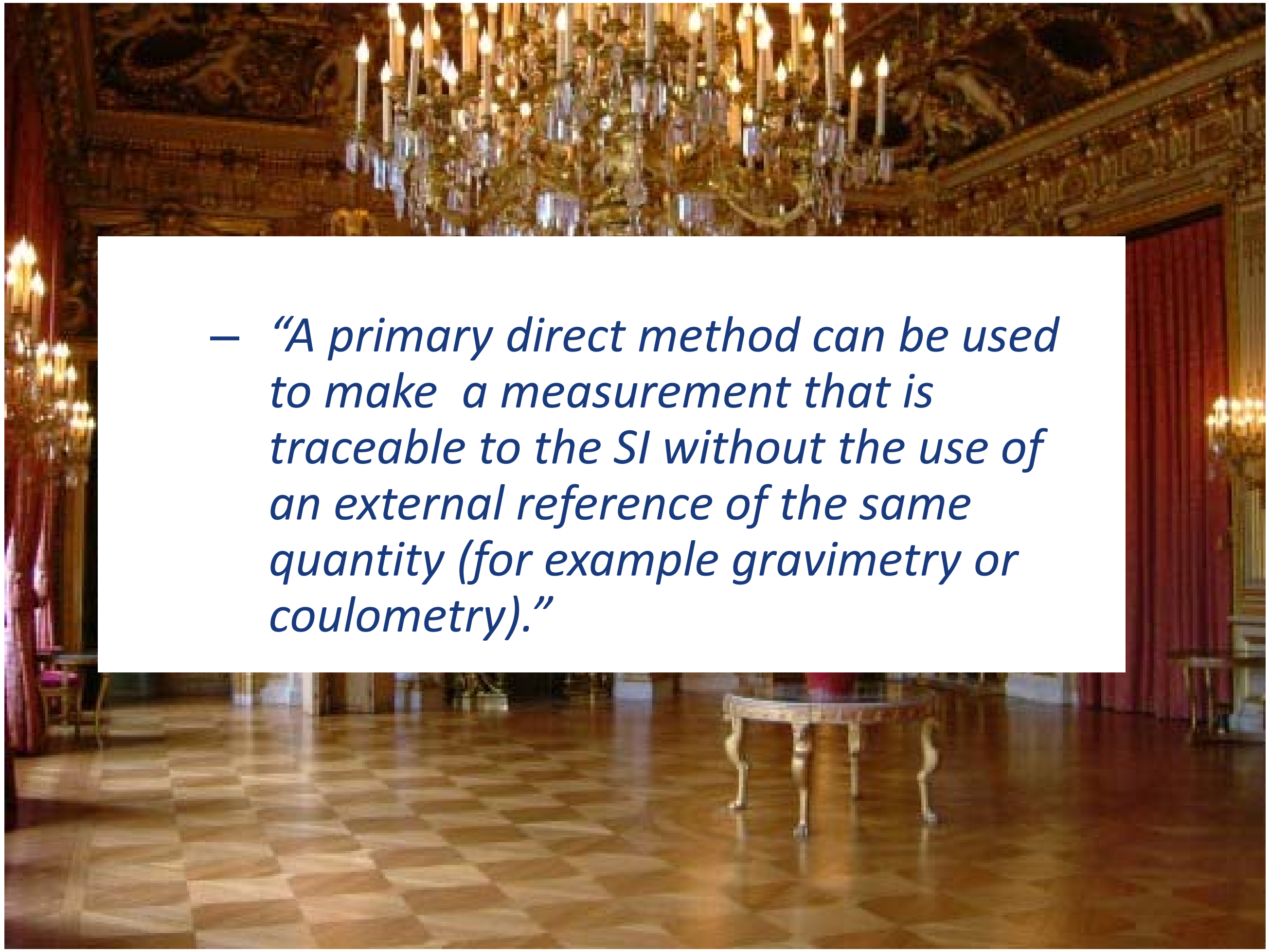
The Grande Salle Metaphor

sample

result

Salon d'Horlorge at the French Foreign Ministry.

The Grande Salle Metaphor



– *"A primary direct method can be used to make a measurement that is traceable to the SI without the use of an external reference of the same quantity (for example gravimetry or coulometry)."*

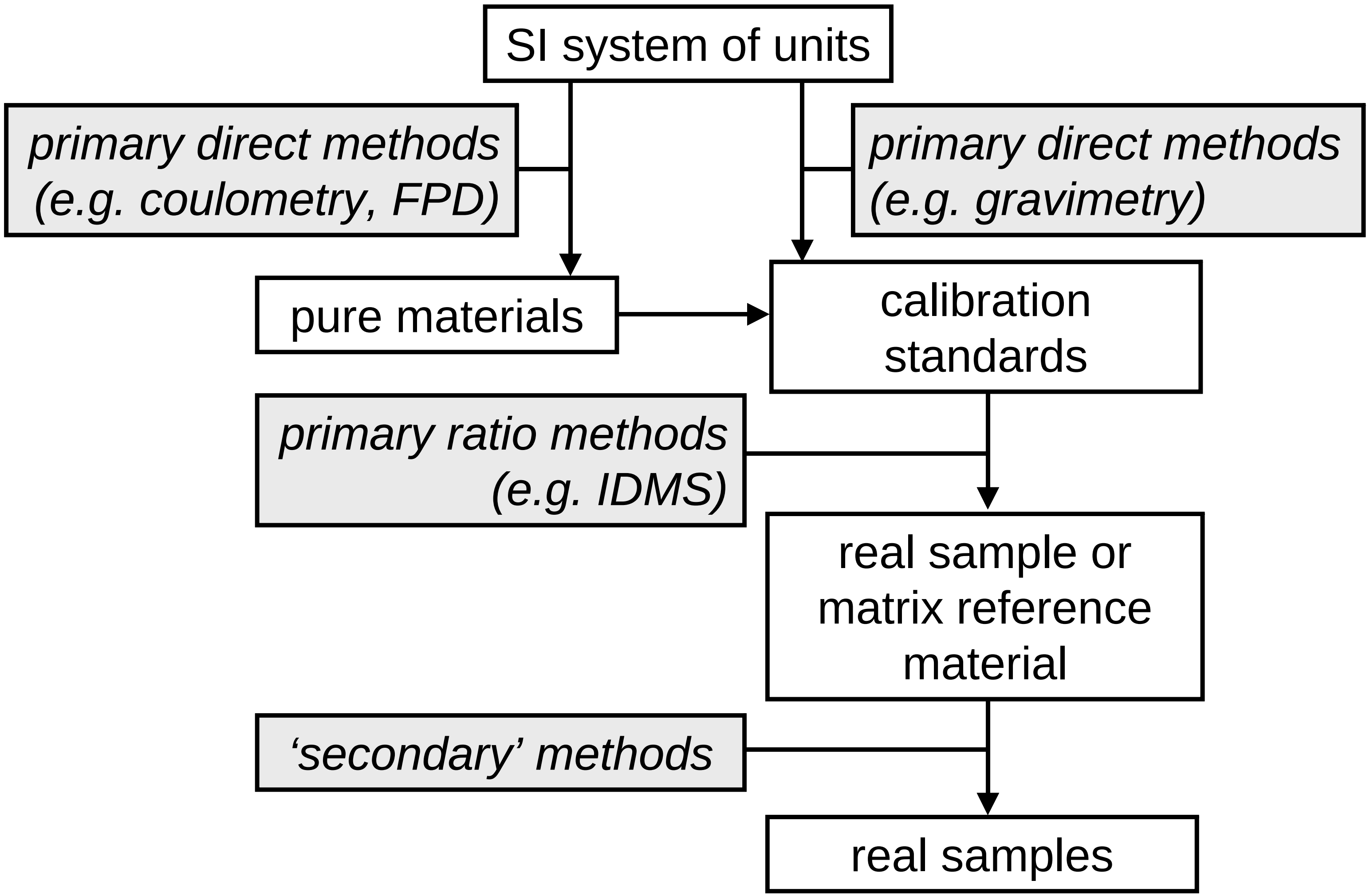
Salon d'Horlorge at the French Foreign Ministry.

Primary method of measurement

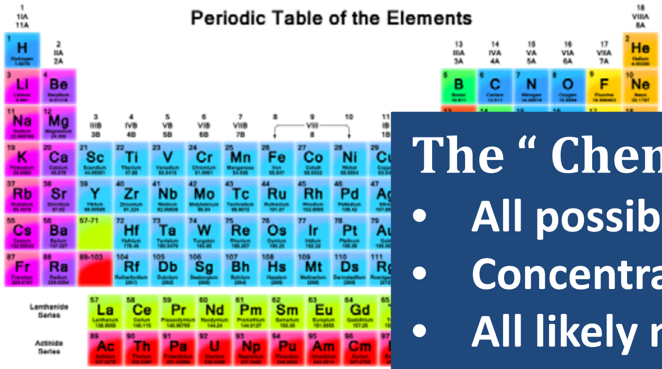
A primary method of measurement is a method having **the highest metrological properties**, whose operation can **be completely described and understood**, for which **a complete uncertainty statement can be written down in terms of SI units**.

- A primary direct method: measures the value of an unknown without reference to a standard of the same quantity.
- A primary ratio method: measures the value of a ratio of an unknown to a standard of the same quantity; its operation must be completely described by a measurement equation.

A general traceability scheme for chemical measurements



The scope of chemical measurements



The " Chemical Measurement Universe"

- All possible chemical compounds
- Concentrations from ppt to "pure"
- All likely matrices (from minerals to shell fish
- Other possible compounds present

But – **we only have finite resources!**

- Every method we develop and
- Every reference material we prepare and
- Every comparison we carry out

must have the widest possible relevance.

How far does the light shine"

- **How far does the light shine?**
  - *"If we test the capability to measure substance X in matrix Y, how many other substances and matrices can we deduce performance about*?"
  - Invented because of the need to limit the number of CMCs in chemistry.
  - It is now of much more general importance

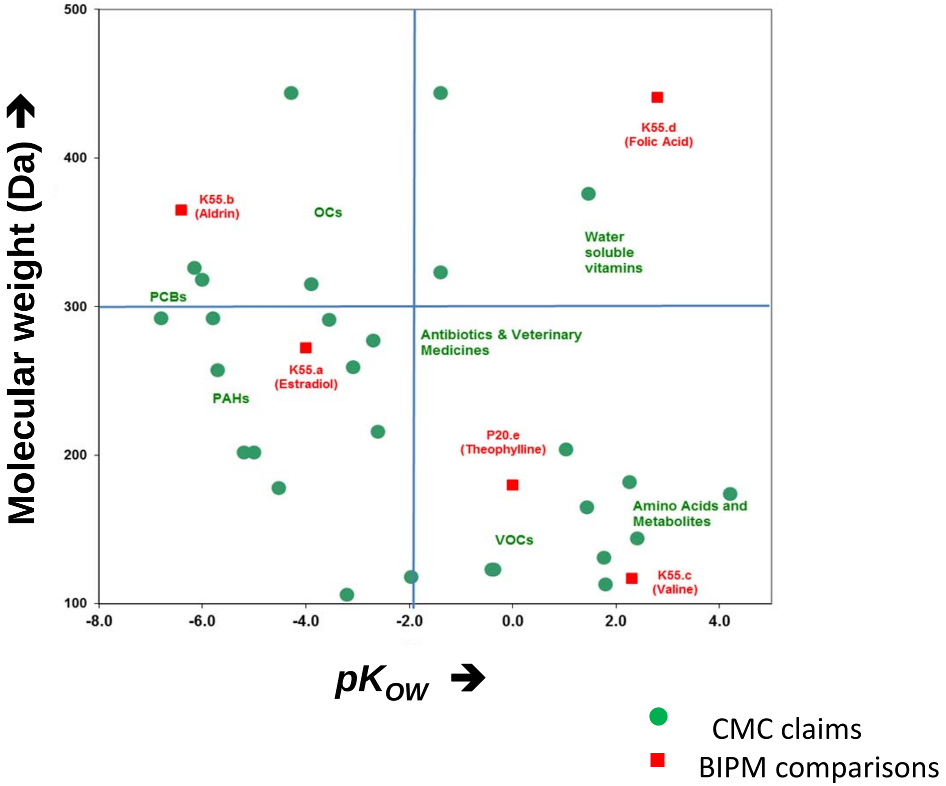
How far the light shines (example 1)

The analysis of organic compounds is an essential part of many different fields of analysis, including environmental, food, clinical, pharmaceutical, drugs of abuse, and forensics.

BIPM Organic Comparison Program me

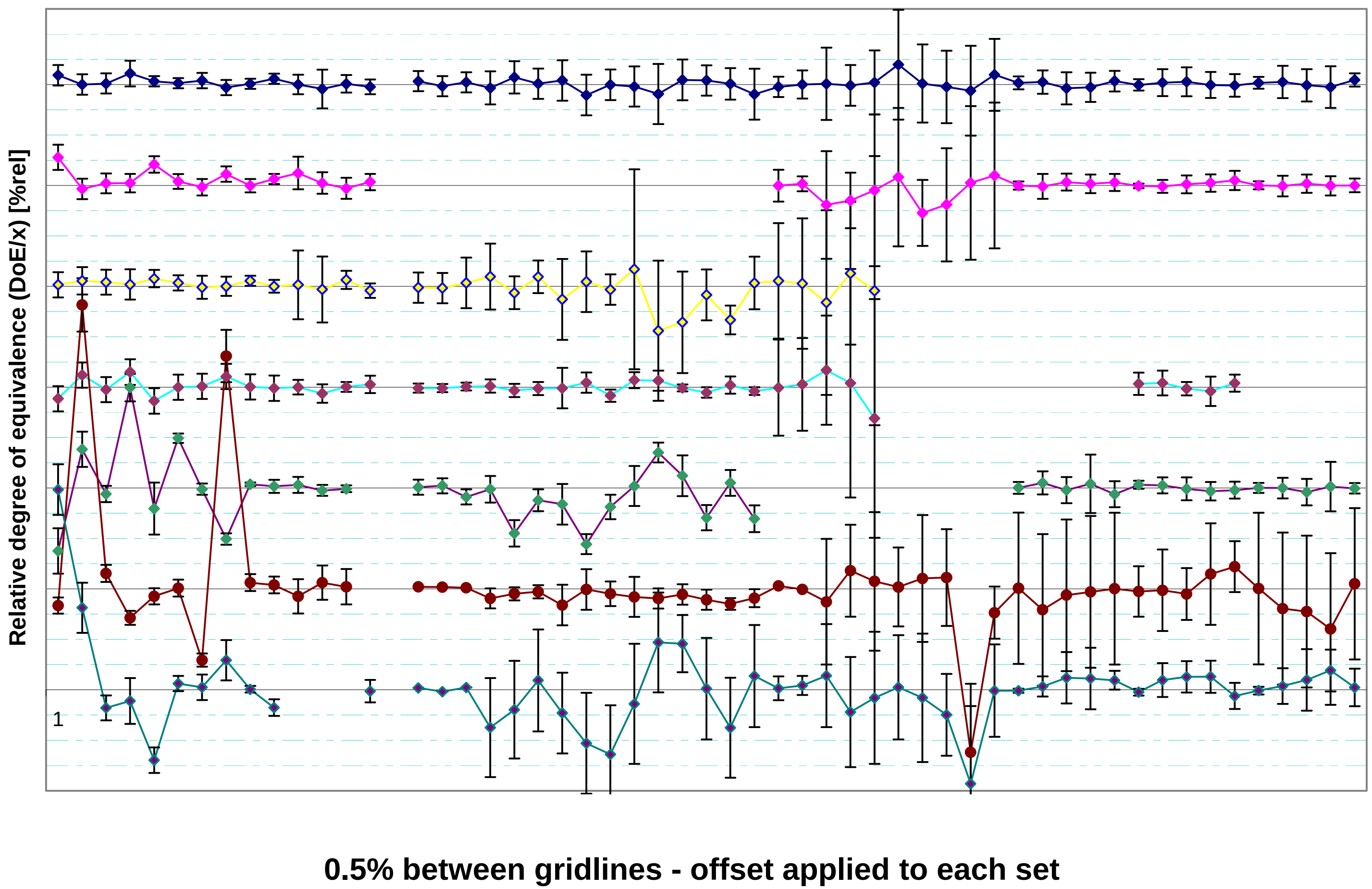
BUT
the "universe" of possible organic compounds is enormous.

So
How far does the light shine?



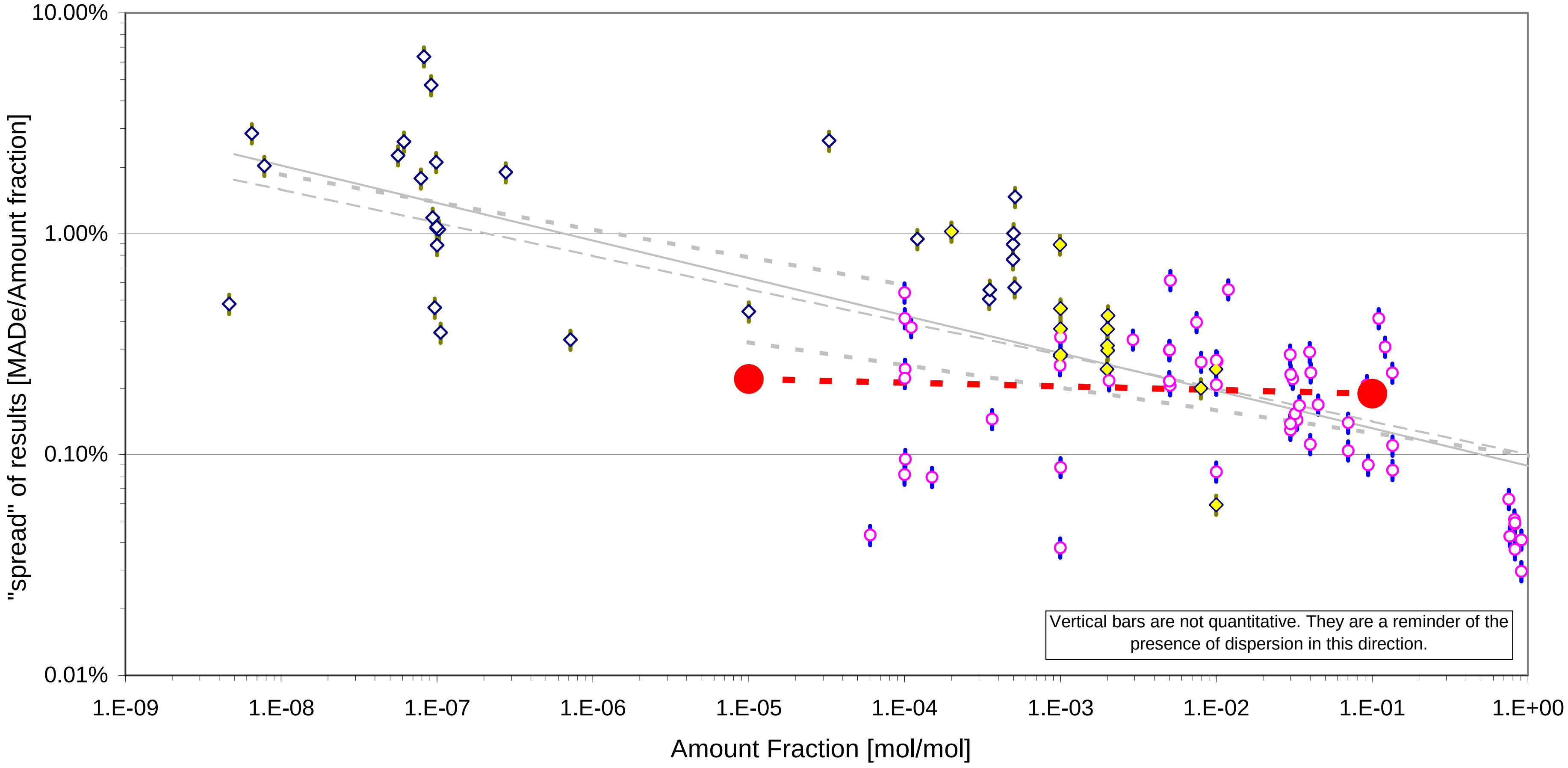
How far the light shines (example 2)

Gas analysis is an essential part of many different fields such as monitoring air quality, atmospheric composition and the contents of energy gases.



How far the light shines (example 3)

How does performance vary with concentration?



There is only small variation of performance with concentration.

Therefore comparisons do not need to be repeated at every concentrations

Summary – metrology in chemistry is different

In many respects, metrology in chemistry is different to metrology in physics:

- The range of requirements is enormous,
- Identifying the chain of traceability is often difficult,
- Dissemination is mainly through the distribution of reference materials
  - can be produced in large numbers ,
  - but a very wide possible range is needed.
- Often driven by regulation,
  - very few “metrology law” / legal metrology requirements in place
  - Many regulations for quality of food, air, water etc.
- Limited accreditation infrastructure,

How is the worldwide measurement system evolving?

And **how is the role of the NMIs developing?**

What we learn from the *Comité consultatif pour la quantité de matière – métrologie en chimie*

- **Only a half of all Member States and Associates take part**
  - 24 out of 55 Member States have >10 CMCs in chemistry
  - 51 out of 55 Member States have CMCs in physics
  - 17 out of 37 Associates have CMCs in chemistry

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- **Designated Institutes play an important role**
  - 24% of chemistry CMCs are from DIs
  - (14% of all CMCs are from DIs ; but 32% in Ionizing Radiation)

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- **Designated Institutes play an important role**
  - 24% of chemistry CMCs are from DIs
  - 14% of all CMCs are from DIs (but 32% in Ionizing Radiation)
- **Key comparisons are mainly organized at the CCQM level**
  - 15% of Chemistry comparison are organized by the RMOs
  - (41% of physics comparisons are organized by the RMOs)
- **Key Comparisons are completed quickly**
  - 74% of CCQM comparisons are listed as "complete"
  - (61% of all comparisons are listed as "complete")

Conclusions

- Application of metrology to chemistry (and biology) has potentiel for great impact.
- The fields are enormous - we can only ever hope to provide traceability (or a measurement infrastructure) for measurands that are representative of whole areas of similar measurements.
- We have to understand « How far the light shines ? »
- Our approach to chemical measurement is enabling us to approach biological measurements
    - as molecular weights get larger, the « IU » can be made traceable.
- Chemical and biological measurements are very method dependant
    - this threatens our concept of coherent measurements
    - but, many new methods are being developed with properties that are well suited for use in metrology: CRDS, IDMS, q-NMR, d-PCR …
- At present, these methods only solve a limited number of the challenges in chemical and biological measurement, but they indicate what can be done.

Thank you

Bureau International des Poids et Mesures