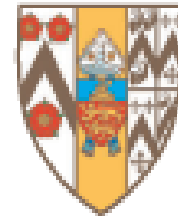
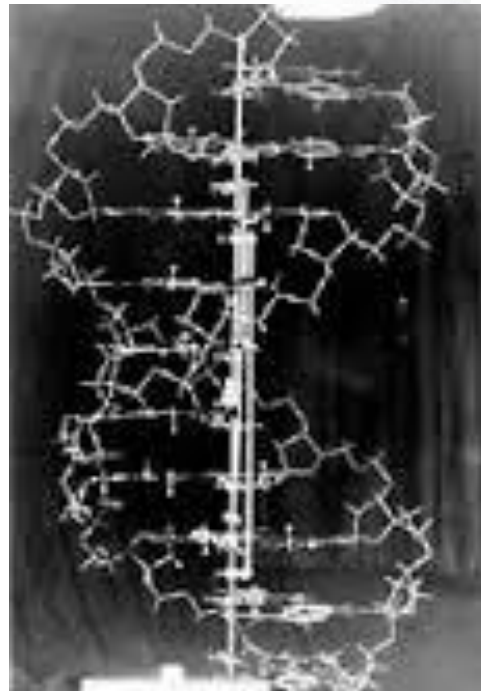
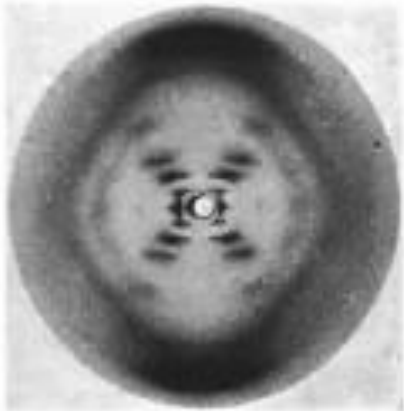


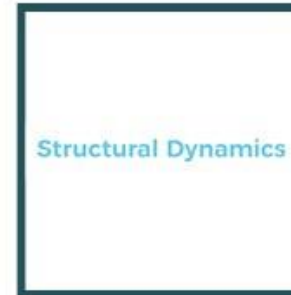
Tribute to Rosalind Franklin

101 years on: her pivotal research on coal, DNA and viruses.

ACA Virtual meeting, 2nd August 2021



Thanks to the ACA sponsors

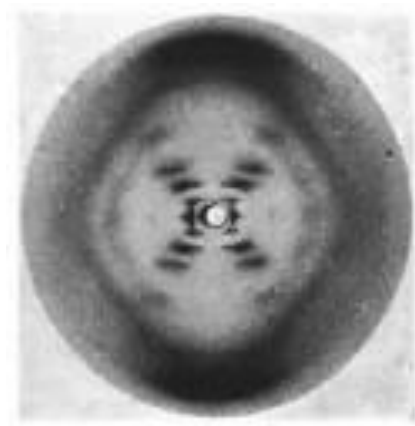




Rosalind Franklin

Tribute

The Plan:



- **Introduction: early life**
- Coal and graphite
- DNA
- Viruses
- The future?

Rosalind Franklin

25/7/1920-16/4/1958

- Born London to Muriel and Ellis Franklin. Brother, David, one year older, two younger brothers (Colin and Roland), and a younger sister, Jenifer (Glynn).

- Rosalind aged 6, her Aunt Mamie Bentwich on a Cornish holiday with the family, said:

“R is alarmingly clever – she spends all her time doing arithmetic for pleasure & invariably **gets her sums right**”

- Aged 9-11 Boarding school at Bexhill-on-Sea





Rosalind Franklin

25/7/1920-16/4/1958

Physical chemist and
X-ray crystallographer

- Aged 12-17 St Paul's Girls' School 'Every girl is being prepared for a career. The High Mistress considers that no woman has a right to exist who does not live a useful life'... 'look beyond marriage as your goal'.



RF excelled at both sport and in her studies.

- Aged 16: her mother 'All her life, R knew exactly where she was going, and at 16 she took science as her subject.' **All her life it came straight from the heart.'**





Rosalind Franklin 25/7/1920-16/4/1958

Physical chemist and X-ray crystallographer

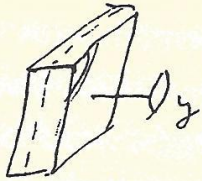


- Summer 1938. Visit to Paris – perfected her French: loved France, the French people and all things French (+hiking & mountains).
- 1938-41 Newnham College, Cambridge, Natural Sciences/Chemistry
- Thought nothing of riding home to London at the end of term on her bike (105 km)!
- 2nd in all her year group in 1st year exams (‘Prelims’)
- 1939. Note to self with a sketch of a helical structure of nucleic acid ‘Geometrical basis for inheritance?’
- Final year research project supervisor Fred Dainton, photo and polymer chemistry, went well.



Learning crystallography at Cambridge

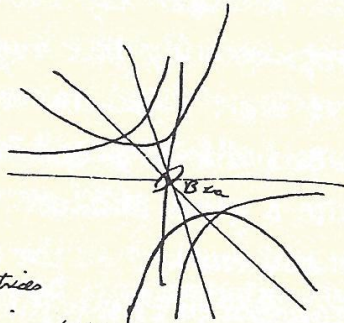
I Monoclinic



y must be || to one principal direction X or Y or Z

Ⓐ $y = B \times a$

crossed dispersion rotation



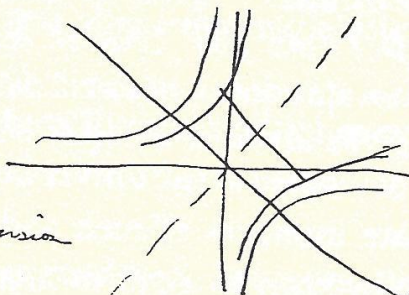
e.g. Borax

- dispersion of bisectrices combined with dispersion of 2V

Ⓑ $y = B \times c$

plane of symmetry

horizontal dispersion

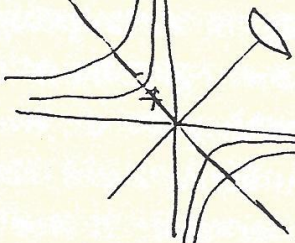


e.g. Sanidine (a feldspar)

Ⓒ $y = Y$

yellow red

inclined dispersion



inclined dispersion

e.g. gypsum

yellow red

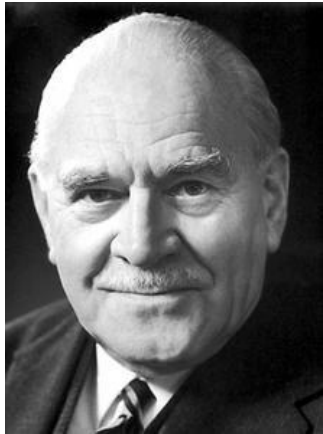
RF's notebook headed 'Crystal Physics' shows her learning the space groups and various crystal forms. Autumn 1939, 2nd year

Rosalind Franklin 25/7/1920-16/4/1958

Physical chemist and
X-ray crystallographer



- 1941-42: 4th year scholarship from Newnham. Research supervisor was RGW Norrish ‘bad-tempered and autocratic treatment of juniors’ impossible project on polymerisation of formic acid and acetaldehyde
- Claustrophobic: small dark room
- Confrontation when cornered was her tactic (Norrish)
- She ‘didn’t suffer fools gladly’.
- Women were not awarded degrees from Cambridge until 1947 (in Oxford it was 1921!)



Norrish





Rosalind Franklin 25/7/1920-16/4/1958

Physical chemist and X-ray crystallographer

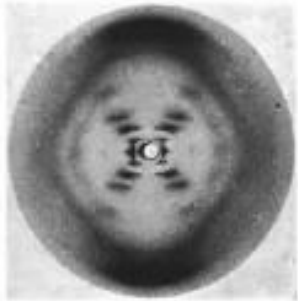
- 1942-1945 PhD registered at Cambridge but worked in Kingston for the British Coal Utilisation Research Association (BCURA) on permeability and shrinkage of coals to gas (helium) and water as a function of temperature. ‘Assistant Research Officer’
- Air raid warden in WWII.
- 1945: PhD thesis title: “The physical chemistry of solid organic colloids with special reference to coal and related materials”



Rosalind Franklin 1920-1958



- 1946: First paper. Trans. Farad. Soc. Hypothesis of ‘molecular sieves’. Very important for gas masks.
- 1947- 51: Paris, Postdoc, studied coal & graphite under Jacques Mering (trained by Bragg) at the Laboratoire Central des Services Chimiques de l'Etat (Govt Lab). Got ‘unEnglished’. Pay: £5/week, rent £3/month
‘women engaged as equals’
- 1951- 53 King’s College, DNA fibres (under Randall)
- 1953-1958 Birkbeck College, viruses, RNA, senior scientist (under ‘Sage’ Bernal)





Rosalind Franklin

Tribute

The Plan:

- Introduction
- **Coal and graphite**
- DNA
- Viruses
- The future?

Coal: anthracite



Brown coal: lignite



Coal: bituminous

graphite



THERMAL EXPANSION OF COALS AND CARBONISED COALS.

BY D. H. BANGHAM AND ROSALIND E. FRANKLIN.

Received 19th August, 1946.

The coefficient of thermal expansion of a solid, being determined by the vibrational amplitudes of an orchestra of atomic—and larger—oscillators, should depend on its molecular constitution rather than upon the physical structure on a colloidal scale of magnitude. With the important reservation discussed in the next section, it can be regarded as an intra-micellar property rather than one concerned with micellar surfaces and inter-micellar contacts. Its variation as between different specimens of coal was expected to throw light on a number of obscure questions, as, for example :

1. whether or not the anisotropy of coal—the mechanical properties of which vary markedly with orientation with respect to the “ bedding ” plane—extends to the atomic (or molecular) dispositions within the micelles ;
2. whether or not there is any marked trend in the size or nature of the dynamic unit of structure with increasing “ maturity ” of the coals ;
3. whether the important changes in the technical qualities of coal engendered by preheating below 300° c. (such as the suppression of “ caking properties ”) are associated with intramicellar chemical change, or confined to the micellar surfaces and contacts. Aside from the other forms of chemical change, any variation in the size or number of the dynamic units—whether brought about by condensation, polymerisation or cross-linking—would be likely to reveal itself in a dependence of the expansion coefficient upon temperature of pre-treatment.

RF first peer
reviewed
published
Paper (of 37)

Trans.
Farad.
Soc,
(1946)
48: 289

**2) First observation of aromatic
bond density: a ‘forgotten’
paper by Rosalind E. Franklin**

Alexander Nazarenko

Chemistry Dept, SUNY Buffalo State

3) Rosalind Franklin and the Structure of Graphitic Carbons

Margaret Schott

Northwestern University

4) Rosalind Franklin, Still Guiding the Development of Carbon Based Materials

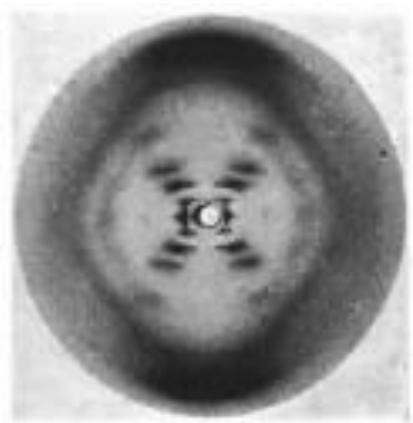
Thomas Fitzgibbons

Analytical Sciences, The DOW Chemical
Company

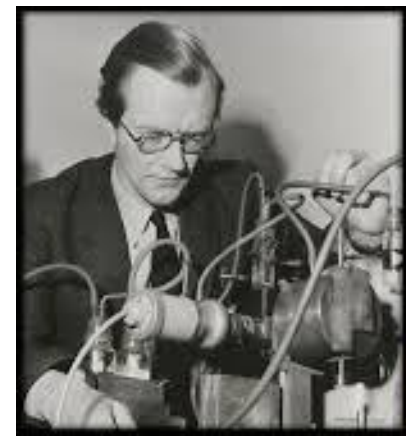
with Abhishek Roy, Surendar Venna

David Reuschle, Shouren Ge, Li Tang,

Michael Clark, Junqiang Liu



Maurice
Wilkins



Rosalind Franklin Tribute

The Plan:

- Introduction
- Coal and graphite
- **DNA**
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- The future?



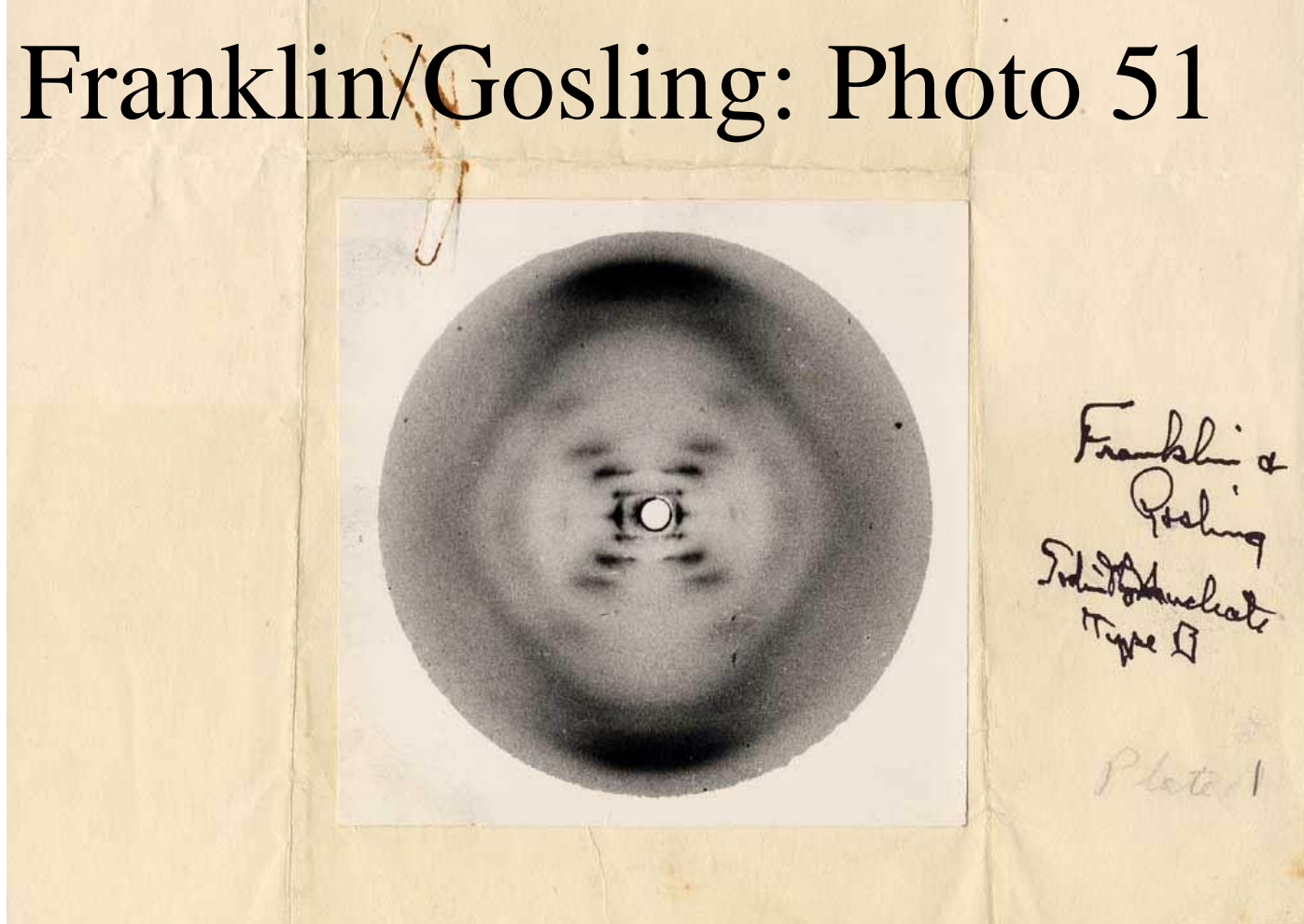
Kings College 1951-53

- Charles Coulsen, Kings: ‘If you are interested in possible biological applications of the technique that you know so well, there could be a lot to be said in favour of Kings.’
- RF: **‘I am, of course, most ignorant about all things biological, but I imagine most X-ray people start that way’**

Kings College 1951-53

- Charles Coulsen, Kings: ‘If you are interested in possible biological applications of the technique that you know so well, there could be a lot to be said in favour of Kings.’
- RF: **‘I am, of course, most ignorant about all things biological, but I imagine most X-ray people start that way’**
- Won 3 year Turner & Newall Fellowship under Randall to work on proteins in solution & changes in structure when they denature, i.e. are heated or dehydrated
- Maurice Wilkins, Kings: got DNA fibres from Rudolf Signer in Berne (May 1950)
- Randall suddenly changed RF’s project to looking at these DNA fibres

Franklin/Gosling: Photo 51



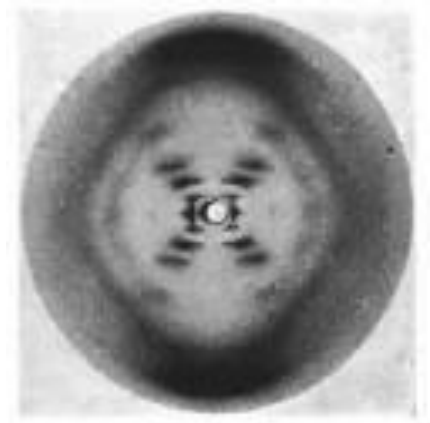
B-DNA (92% humidity) taken at Kings College in May 1952 by
Gosling and RF

X-ray generator was a prototype fine-focus device built at Birkbeck
by Werner Ehrenberg and Walter Spear and given to Wilkins and
Gosling, but then used solely by RF and Gosling

5) Rosalind Franklin and DNA

Brian Sutton,

Kings College, London

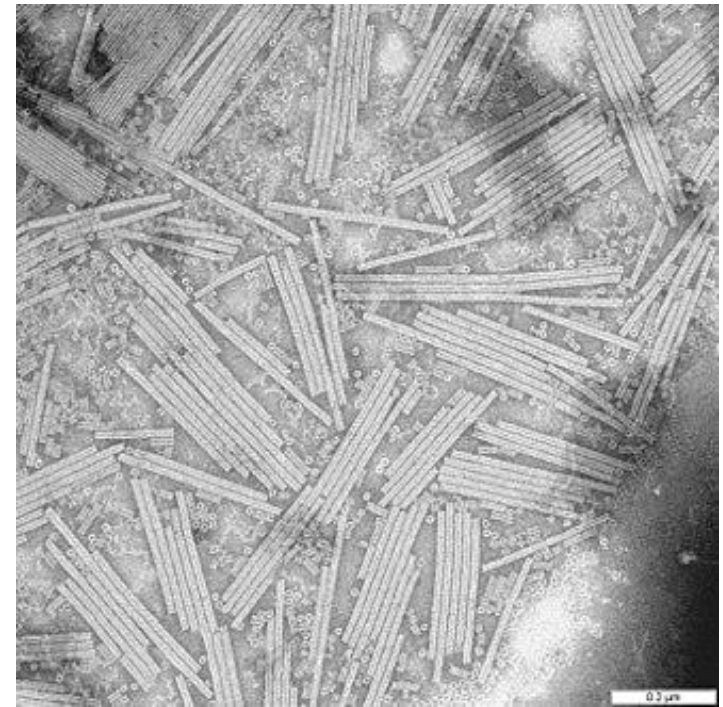
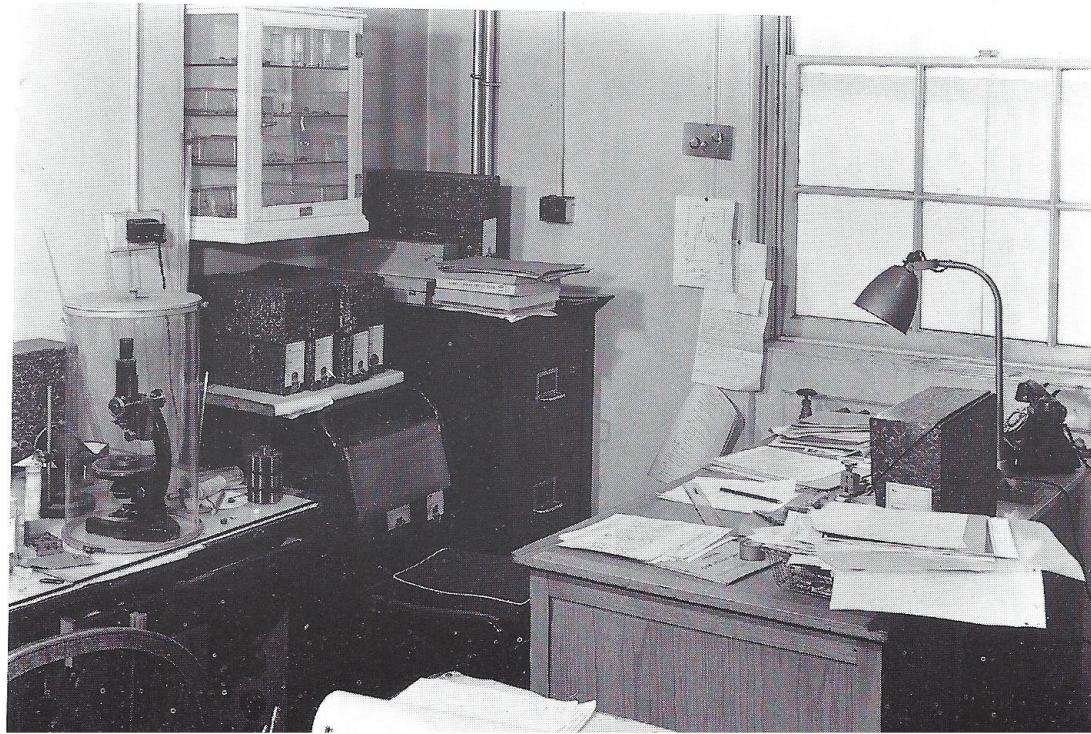


Rosalind Franklin Tribute

The Plan:

- Introduction
- Coal and graphite
- DNA
- **Viruses**
- The future?

Birkbeck College, Mid-March 1953-1958



RF office on 5th floor of bomb damaged house.

‘I swapped a palace for a slum’

X-ray lab in basement. Leaked & needed an umbrella!

Funding from Agricultural Research Council

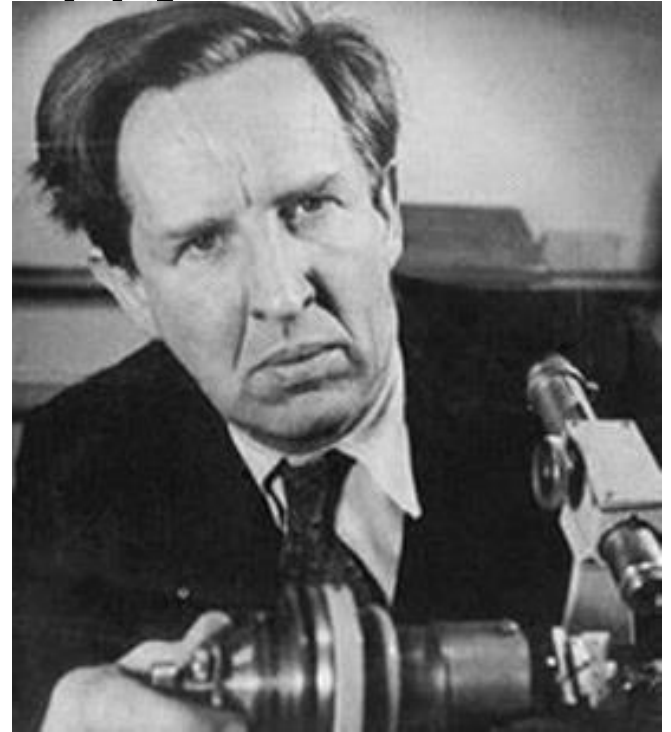
TMV: 1st virus identified

John D. Bernal, supportive happy environment

‘Sage’ thought the world of RF and supported/protected her.

‘brilliant experimentalist’

‘As a scientist, Miss Franklin was distinguished by extreme clarity and perfection in everything she undertook. Her photographs are among the most beautiful X-ray photographs of any substance ever taken.’



6) Rosalind Franklin and her legacy in structural biology; the TMV chapter

Gerald Stubbs

Vanderbilt University

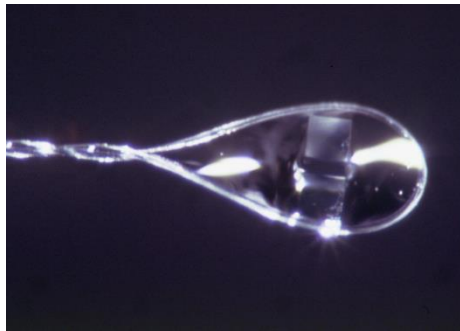
with Joseph Orgel

Illinois Institute of Technology

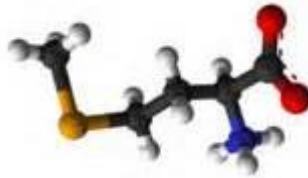
Developments during the last 50 years in protein crystallography:



*



*



*



* cited in the 2009 Chemistry Nobel Prize scientific background as important for the ribosome structure solution [Garman, Science, 2013]

1989: 2.9 Å Foot and Mouth Disease Virus Structure

- Structure is allowing design of new more stable and safer vaccines

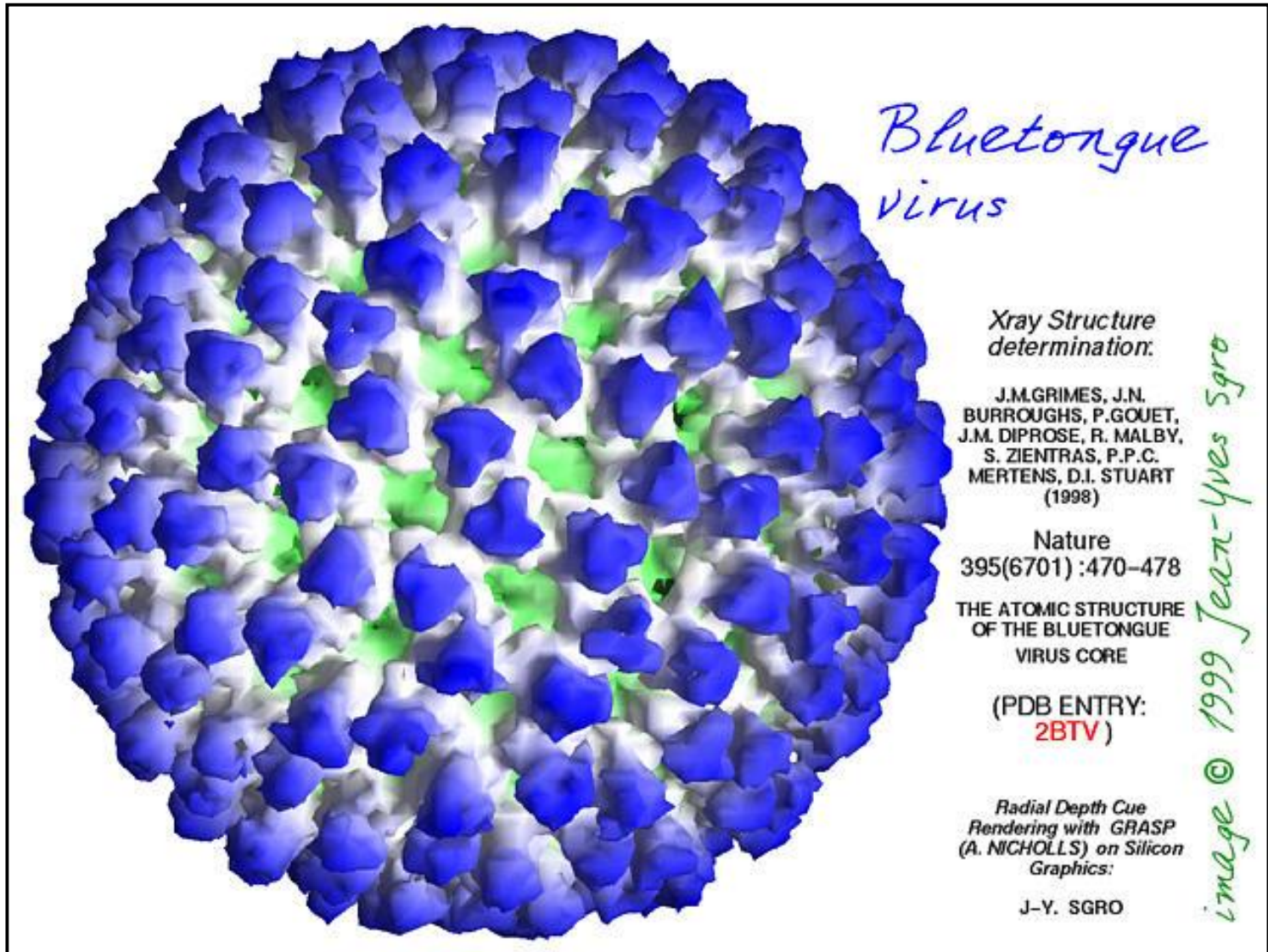


25-30 nm

1 nm = 1 millionth
of a mm.

Acharya et al.
Nature 1989

100nm



Virus structure determination by X-ray crystallography

A Nobel Prize for Rosalind Franklin?



- **DNA Structure**

The Nobel Prize in Physiology or Medicine 1962

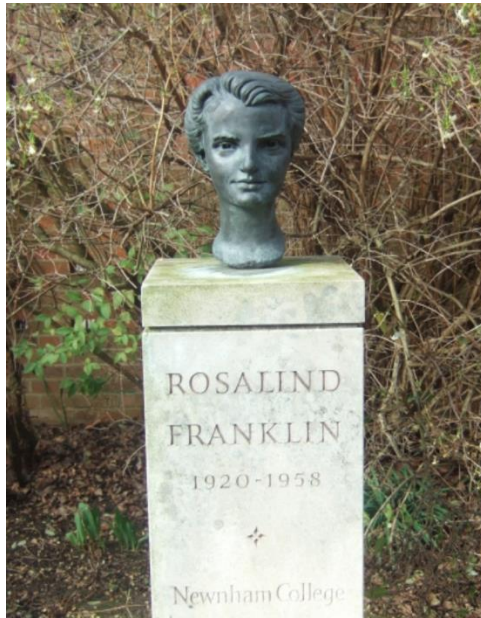
Francis Crick, James Watson, Maurice Wilkins

"for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material."

- Max 3 people, never awarded posthumously



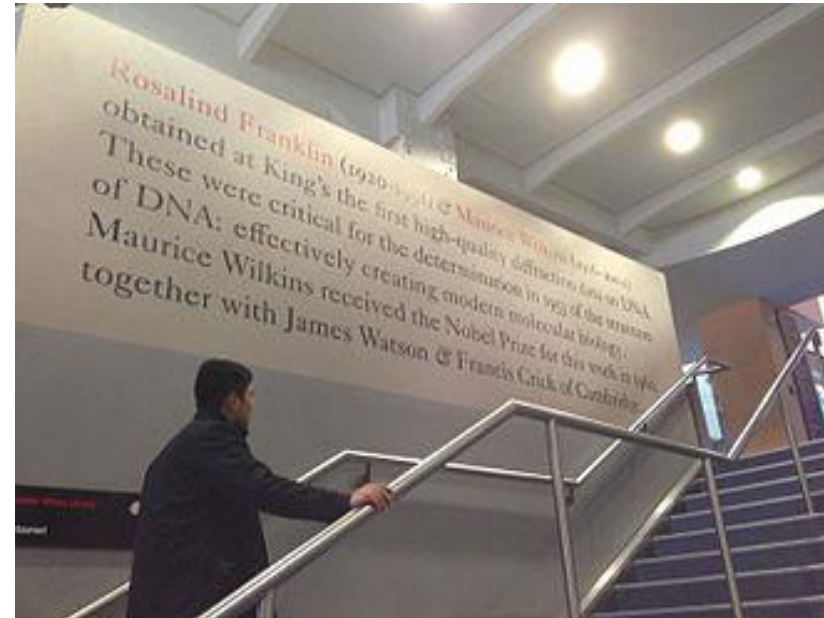
Posthumous recognition



Newnham College,
Cambridge



Kings College,
Franklin-Wilkins Building



Rosalind Franklin
University of Medicine
and Science, Chicago,
Illinois, USA

39 listed on Wikipedia

- 2017, the Historic England listed the tomb of Franklin under the Planning Act 1990 as a "special architectural or historic interest". Official description: "the tomb commemorates the life and achievements of Rosalind Franklin, a scientist of exceptional distinction, whose pioneering work helped lay the foundations of molecular biology; Franklin's X-ray observation of DNA contributed to the discovery of its helical structure. It is in "Willesden Jewish Cemetery, London and bears the epitaph '
`Rosalind Elsie Franklin...

Scientist, Her research and discoveries on Viruses remain of lasting benefit to mankind.'

3 more of the 39 listed on Wikipedia

- 2018, Rosalind Franklin Institute, autonomous medical research centre under the joint venture of 10 universities and funded by UK Research and Innovation, launched at the Harwell Campus
- 2019, the European Space Agency (ESA) named their ExoMars rover *Rosalind Franklin*.
- 2019, the University of Portsmouth announced that it changed the name James Watson Halls to Rosalind Franklin Halls from 2 September.

WOMEN IN SCIENCE

- 50 FEARLESS PIONEERS -
WHO CHANGED THE WORLD

WRITTEN AND ILLUSTRATED BY
RACHEL IGNOTOFSKY



DID CRITICAL WORK ON MOLECULAR STRUCTURES
OF DNA, RNA, VIRUSES, COAL & GRAPHITE.

DISCOVERED THE DNA DOUBLE HELIX.

PIONEERED RESEARCH ON THE
TOBACCO MOSAIC VIRUS & POLIO.

'SCIENCE AND EVERYDAY LIFE CANNOT AND SHOULD NOT BE SEPARATED.' - ROSALIND FRANKLIN

ROSALIND FRANKLIN

CHEMIST AND X-RAY CRYSTALLOGRAPHER

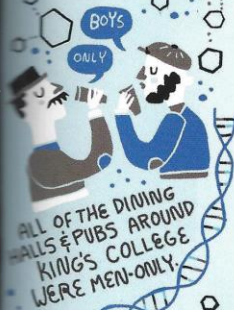
Rosalind Franklin was born in 1920 in London. Her father disapproved of women going to university, but she went on to earn a PhD in physical chemistry from Cambridge.

The big question of the day was 'What is the shape of DNA?' Scientists knew that DNA formed the building blocks of the body, but they had no idea what it really looked like. Rosalind Franklin was on the case at King's College.

She spent hours using an X-ray on the delicate fibres of DNA, capturing a famous photo proving DNA is a double helix. Meanwhile, two scientists, James Watson and Francis Crick, were also trying to figure out the structure of DNA. They peeked at Rosalind's work without her permission, and used

her findings to publish their own work without giving her credit. Rosalind left the toxic work environment of King's College and continued her research. She went on to a top research lab and started researching the tobacco mosaic and polio viruses.

Rosalind died from cancer in 1958 at only 37; Watson and Crick won a Nobel Prize four years later. Watson wrote scathing comments about Rosalind in his book *The Double Helix*, also admitting that he had looked at her data. People started to figure out what really happened, and Rosalind is remembered as a woman who should have won a Nobel Prize. Now that we know her story, we can celebrate all that she accomplished!



ALL OF THE DINING HALLS & PUBS AROUND KING'S COLLEGE WERE MEN-ONLY.



PHOTO 51 PROVED THE DOUBLE HELIX STRUCTURE.



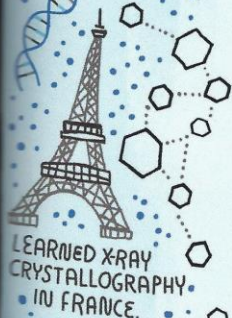
KNEW SHE WANTED TO BE A SCIENTIST WHEN SHE WAS 15 YEARS OLD.



CREATED A HUGE, ACCURATE TOBACCO MOSAIC VIRUS SCULPTURE FOR THE WORLD'S FAIR.

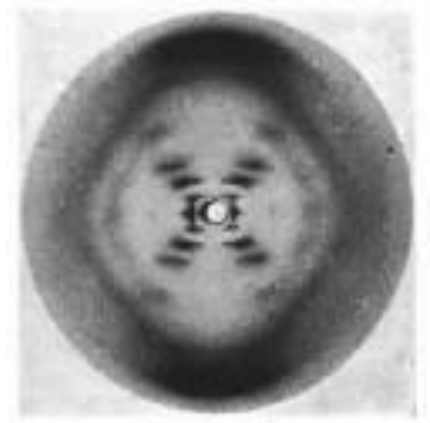


RESEARCHED CHARCOAL TO BE USED IN GAS MASKS DURING WWII.



LEARNED X-RAY CRYSTALLOGRAPHY IN FRANCE.





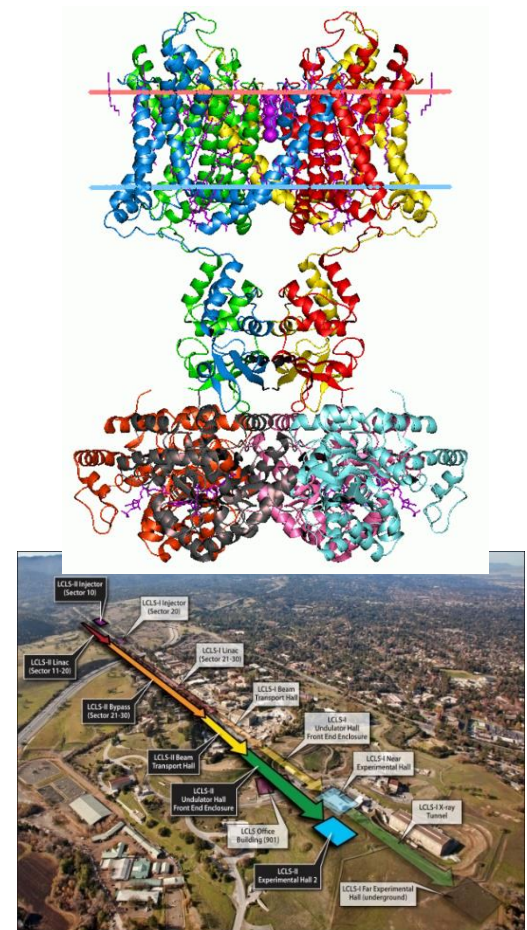
Rosalind Franklin Tribute

The Plan:

- Introduction
- Coal and graphite
- DNA
- Viruses
- **The future?**

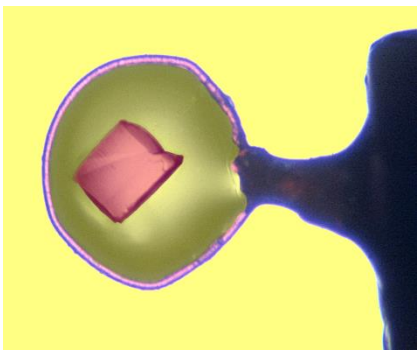
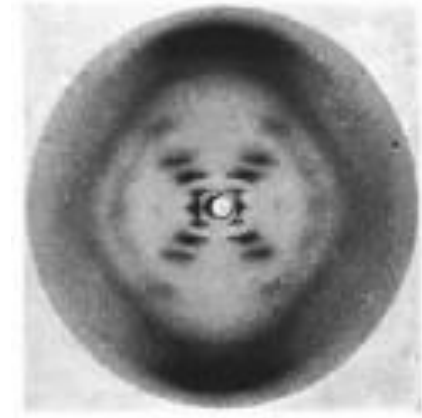
The next 100 Years?

- We have determined many structures now, but we need their function too.
- Membrane protein crystallography: still in its infancy. Much to learn.
- Single particle imaging of protein molecules with Free Electron Lasers?
- Bioinformatics – more powerful algorithms using modern computing power.
- Protein structure prediction (AlphaFold2) may eventually obviate the need for crystals or real experimental X-ray data, but never for big protein complexes (Cusack, 4/2/20)
- Many more high resolution structures determined by electron microscopy.



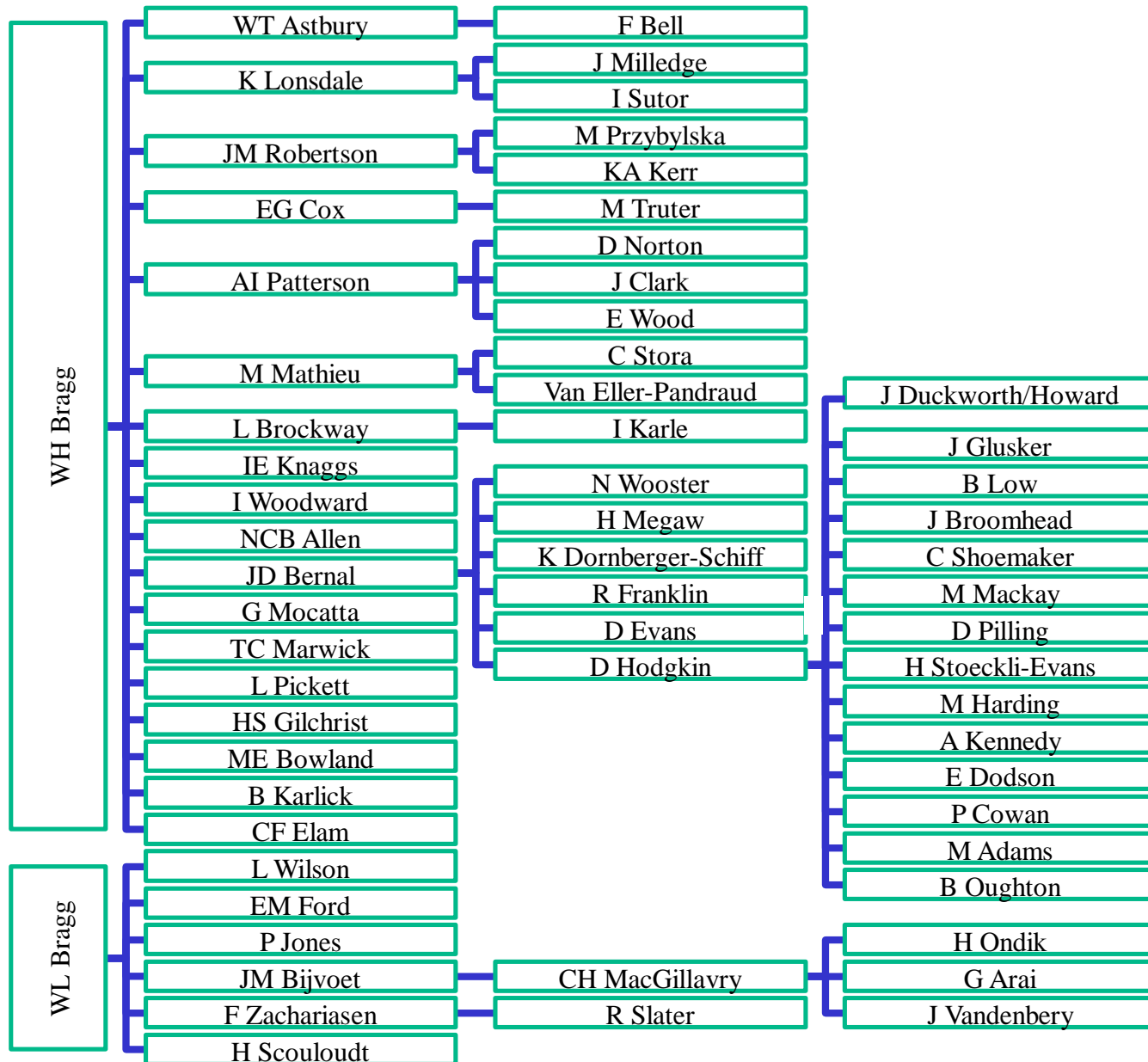


THANK YOU FOR LISTENING!

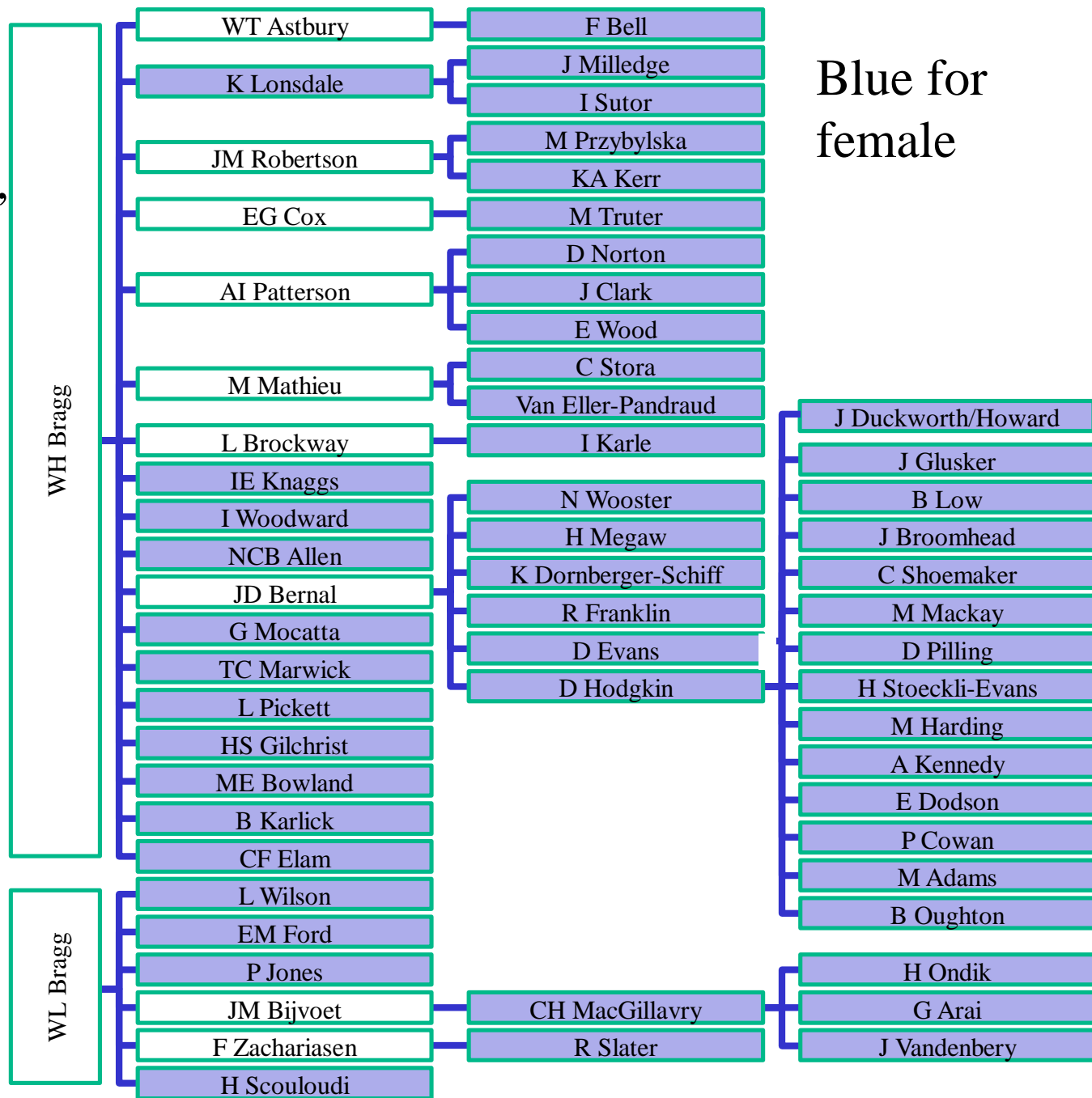


elspeth.garman@bioch.ox.ac.uk

The Bragg Legacy >100 years on



Maureen M. Julian,
 “Women in
 Crystallography,”
 in *Women of
 Science: Righting
 the
 Record*, ed. G.
 Kass-Simon and
 Patricia Farnes
 (Bloomington:
 Indiana University
 Press,
 1990), pp. 342
 (JAKH added)



Kathleen Lonsdale
 Rosalind Franklin
 Isabella Karle
 Helen Megaw
 Dorothy Hodgkin
 Louise Johnson
 Eleanor Dodson
 Marjorie Harding
 Jenny Glusker
 Ada Yonath
 Judith Howard
 and many others

Also:

Live up to the Light thou hast + more will be granted thee. X-ray
 ◉ SCIENTISTS ◉
 Atomic Chemist ◦ Astrophysicist ◦ Crystallographer

John Dalton FRS. 1766-1844
 Dame Kathleen Lonsdale D.Sc. FRS. 1903-71

Brilliant Hot Stars
 Cool Faint Stars
 $4\text{KeGM}(1-\beta)$

Sir Arthur Stanley Eddington O.M. FRS. 1882-1944

C₆(CH₃)₆
 HEXAMETHYL BENZENE

The immensities of ordered space and time, gravitation, and the minute structure of matter set before us by the Scientists enrich and en-noble our idea of the creative processes of GOD.