A CRITICAL ANALYSIS OF

THE NATURE OF THINGS

(to include the play itself)

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ABSTRACT

A critical analysis of the 'science play' *The Nature of Things* examining the dramaturgical challenges of integrating biography, science and art. The overall aim was to create an original, imaginative and coherent theatrical experience for a general audience to access compelling human stories, exquisite phenomena and life-changing ideas that would otherwise be limited to the select few.

The play tells the story of 'Dorothy Hodgkin and Crystallography' interpreted using drama, dance and design/digital media. Crystallography is a powerful technique used to determine the structure of molecules such as insulin and DNA. Other significant characters include Kathleen Lonsdale, Rosalind Franklin, William Bragg, John Desmond Bernal (Sage), as well as Crick, Watson and Wilkins.

The work was crafted to expose a profound emotional connection between the supposedly opposing cultures of science and art.

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Introduction

This critical analysis of *The Nature of Things* examines the work as a ‘science play’. I will reflect on the main challenge of the genre namely interpreting true biographical stories, historical contexts and scientific concepts by finding the delicate balance between ‘traditional’ intellectual text-based dramatic storytelling and a more visual physical experiential performance style. I will discuss the impact of the research and development process on the final piece and explore how key decisions about form and content were realised using dramaturgical strategies.

The overall aim was to create an original, imaginative and coherent theatrical experience for a general audience to access compelling human stories, exquisite phenomena and life-changing ideas that would otherwise be limited to the select few. I designed the play to expose a profound emotional connection between the supposedly opposing cultures of art and science.

The Original Play Proposal

This piece is a celebration of three extraordinary women whose love of science changed our world: Kathleen Lonsdale, the first woman to become a fellow of the Royal Society (1945); Rosalind Franklin whose lack of credit for her role in the 1962 Nobel Prize winning discovery of DNA continues to cause controversy in the public eye (she died aged thirty-seven in 1958) and Dorothy Hodgkin, the only British woman to be awarded a Nobel Prize for science (1964). All three scientists were pioneers in the profoundly consequential new subject of Crystallography, a powerful technique used to determine the structure of molecules such as insulin and DNA.

The play will connect three complementary interpretations of the story of Crystallography. First, there is the unfolding science itself, revealing the biological mechanisms that define us. Second, there is the remarkable web of people that passed the baton of work between each other, fueled by the pursuit of truth, personal ambition and social responsibility. The final interpretation examines the dehumanising implications of technological advances. The other-worldly relationships between these three sides of the same story play out through the interaction between actors (the scientists), dancers (who perform molecular patterns) and projection/scenography/lighting (the technology/apparatus/evidence). This blend of theatrical media will enable the audience to ‘see’ the science through the scientists’ imaginations.

Methodology

Aware of the need to integrate the different elements of my science play from a very early stage, I conducted research alongside writing and investigating choreographic ideas. This involved a good amount of solitary graft and craft, discussions with experts and practical collaboration with a range of theatre practitioners leading to two work in progress performances.

Once I was happy with the script I started to review some of the key dramaturgical choices I had made in preparation for this thesis. It soon became apparent that my intentions and decisions relating to strategies and style have been hugely informed by my reactions to other ‘science plays’. In this way my piece is a response to the existing work in a relatively unexplored genre.

Science Plays as Traditional Drama

Science plays arguably date back to the very early seventeenth century with Marlowe's *Doctor Faustus* and Jonson's *The Alchemist*. In her book *Science on Stage*, Kirsten Shepherd-Barr asserts that the 'history of science presents inherently dramatic material: "great feuds", high stakes, intense competition, and extremes of elation and disappointment' (2006, p. 51). The trend in creatively exploiting famous scientists' lives began with Brecht's *Galileo*. Scientific concepts and the process of scientific endeavour have since been incorporated into a great many plays by established playwrights including Frayn (*Copenhagen*), Stoppard (*Arcadia, Galileo* and *Hapgood),* Wertenbaker (*Galileo's Daughter, After Darwin)* and Churchill (*A Number*). These works demonstrate how science can provide extremely effective theatrical metaphors to investigate who we are and our place in the universe. In fact Stoppard took this idea literally when he intended his play *Galileo* to be performed in the site specific venue of the London Planetarium.

Intertextuality

The fact that Stoppard and Wertenbaker, to name but two, felt the need to respond to Brecht's original version of *Galileo* by historically correcting and expanding on Brecht's portrayal of events demonstrates that even amongst 'pure' playwrights, science plays have a propensity for intertextuality due to differing priorities in dissecting 'truth' from the same raw subject matter.

Ever since Watson (1997) wrote the *Double Helix* and Rosalind Franklin became famously branded as a 'wronged heroine' there has been a lasting public interest in

the controversy surrounding credit allocation for the discovery of DNA and the way Rosalind was treated as a woman. Unconventional heroines are ideal material for plays, so it is unsurprising that she has inspired several dramatisations including Deborah Gearing's *Rosalind: A Question of Life* (2006) and more recently the award winning *Photograph 51* by Anna Ziegler (2010). Part of the reason that the story continues to capture interest is that it is difficult to reconcile the many facts into a single easy truth. This led to a heated exchange involving the *New York Times* science journalist Nicholas Wade after a performance of Ziegler's (2010) play:

> the idea that Rosalind was robbed of credit is incorrect. It is also incorrect that she was discriminated against because she was a woman... Anna's play.. falls into the mythological treatment of this important discovery and not on to the historical facts... Although the dramatist has every license to invent conversation, to mix up times and places, of course that is their license. But the bottom line is it has to be true to some message... I didn't hear a true message in the play. (Mirsky, 2010)

Balancing all the facts into a 'true message' can be a subtle matter. Just as my opinion about the DNA saga was beginning to settle, new information kept coming to light: a brilliantly refreshing positive account about the treatment of women at Kings College from Raymond Gosling (Rosalind's PhD student); a contradictory impression in a coincidental conversation with a lady whose husband had worked at Kings College; the discovery of a new set of Crick-Wilkins letters containing damning quotes in 2010 and finally in 2011 I saw Watson in person at an organised Public Conversation with Brenda Maddox (Rosalind Franklin's biographer). Maddox asked

Watson if Rosalind should have received the Nobel Prize, to which he replied ‘they don’t give Nobel prizes for failure’ (Maddox, 2011; and 2.1) and so, successfully shocked his entire audience.

Copenhagen

The Nature of Things has a number of features in common with *Copenhagen.* Both plays have an acute awareness of the audience as an observer and deliberately draw attention to the good match between the actual environment of a theatre auditorium and a lecture hall. One method I used to do this was to plant actors playing students or scientists amongst an unsuspecting audience, subverting their preconceived ideas about the nature of delivering and receiving lectures. I exploited the performance aspect of a lecture experience by having a performer dance out ideas at the pace and speed of the lecturer’s spoken delivery. I also introduced the risk that observers in the audience can suddenly be put on the spot and transform into performers in the show. The purpose of this was to encourage audiences to actively think and examine the play metaphysically. Although I associated each ‘lecture event’ with a specific location to ground it in time and space, they really operated on the level of pure thought as a meeting place for imaginations.

A significant commonality between the central protagonists in *Copenhagen* and my piece is that they overtly examine their own scientific discoveries and history. My play has the additional element of having a fictional character; the headstrong young student artist Teresa. Like the characters in *Copenhagen*, Dorothy and Teresa are narrators as well as central characters. This allows for dramatic invention. They have considerable control over the chronology of events presented. They can step into

scenes to enact them as well as dipping out of them to comment and question. Their discussions outside the history, science and art project they are officially exploring are integral and dramatic in themselves. These ‘present day’ type scenes are set in March 1990 when Dorothy would have been eighty years old. They chart the development of Dorothy and Teresa’s mother-daughter, teacher-pupil relationship. This finally becomes reversed at the very end of the play when Dorothy crumbles and Teresa mothers her. After being overwhelmed and terrified at the prospect of tackling the science, Teresa achieves her goal of ‘seeing’ the full dance of insulin. She also accomplishes the complementary challenge of understanding Crystallography. She explains its personal and social significance to Dorothy with extreme clarity and momentarily rises to the positional role of teacher and sage.

In *Copenhagen*, the characters are essentially ghosts. Originally I had used the ghosts of Jim Watson and Rosalind Franklin as narrators. This seemed a little absurd as Jim Watson is still very much alive so I preferred to think of them as playing out some sort of dream state brought about by the opposing forces of public consciousness. Teresa didn’t exist yet and although my instinct was that Dorothy was the glue holding the piece together she felt too stable to give the narration an interesting angle. The ghosts in *Copenhagen* work well because there is so much that is unresolved. I chose Rosalind and Watson because their DNA story seemed unresolved. However I eventually realised that the play is primarily Dorothy’s story above the other two original scientists. This was a huge revelation. After experimenting with different ways to tell it, I remembered a conversation I had had with the director of the British Crystallographic Association, Elspeth Garman. Through

researching some comments she had made in an interview I finally understood Dorothy's unresolved issue:

> I know that [Dorothy] would not approve of how we do experiments now. She felt that we weren't well educated Crystallographers... It's all automated. Computers have taken a huge amount of the burden of understanding. There used to be a crystallographer; now you can be a biologist who just uses crystallography. That's the main change philosophically - it's now a technique not a specialism." (Garman, 2010) (Cited in Itzhaki, 2010)

So suddenly the play became about the conflict between technological progress and the declining need for manual and imaginative excellence. The painful irony is that Dorothy herself was hugely responsible for moving the technology on, motivated by her aim to see the atoms and her quest to solve the structure of insulin. Through developing the subject she loves Dorothy simultaneously destroys it. According to David Edgar's theories about *How Plays Work*, the dramatic currency of the play is now 'coping with the loss of a wished for future' and its axis becomes 'the disparity between excellence and results – acting to bring about one end, only to bring about another; or achieving what you aim for, but finding it isn't what you wanted after all' (2009, p.27).

The ghosts in *Copenhagen* inhabit a supernatural timeless world. As there are so many departures from conventional reality in *The Nature of Things*, wherever possible I attempted to give the audience a 'safety rail' of a concrete world located in space and time. I used the prop of the wheelchair as a device to indicate which type of world Dorothy's thoughts are currently in. If she is sitting in the wheelchair she is

concretely in the art college. If she leaves the chair she will have gone back in time. She can experience the world of scientific imagination in parallel with actual situations because it is a partial state. At the most basic level it can be accessed by sensing and seeing the dancers. Each scientist (played by an actor) works through their thoughts as if in conversation with their own muse (their particular dancer); the manifestation of their scientific understanding. The scientists are restricted by extremely pedestrian movement whereas the science they seek to understand is danced with increasing beauty and complexity until each molecular structure is fully revealed. All the characters want to progress to seeing the scientific patterns of their molecular structure performed at the highest possible level of detail as well as comprehending the symmetry and repetition of the core pattern. The characters in the play are often configured in trios and duets which subtly echoes the two-fold and three-fold rotation symmetry in insulin. In a simpler yet similar way, the Blakemore production of *Copenhagen* used the actor's pathways on a circular stage to represent the particle trajectories.

In both plays the performative speech act of remembering, brings the past into the present through replaying and reconstructing significant conversations and scenes. In *Copenhagen* the same meeting is re-enacted differently three times. In my play Dorothy Hodgkin mediates the excavation of the past and is caught out at least once for elaborating on the truth when Teresa asks 'Is that really how it happened?' (1.6).

The two plays deal in 'intentionality'. Why did Heisenberg go to Copenhagen? Why did Dorothy commission the Crystallography portrait? As ever with theatre, there is no single definitive answer to these crucial questions yet the director of the Danish

production of *Copenhagen* thought the actor playing Heisenberg made an interesting attempt at one with his suggestion that Heisenberg wanted to hold Bohr's hand before going through a door he was scared about.

The central complicated human relationship in *Copenhagen* is about playing the roles of a father and son, whereas in *The Nature of Things* the central characters flirt with the roles of mother and daughter. This sets up an anticipation and longing in the audience for some sort of clash followed by reconciliation, potentially symbolised by 'holding hands'. Playwrights including David Edgar (2009, p.94) and Steve Waters (2010, p.157) are keen on the process of setting up, thwarting, subverting and delivering on expectations like this because it stokes an audience's emotional journey. It also enables the audience to relate to the scientists as flawed human beings, or indeed a collection of contrasting flawed human beings. A wider more general question about intentionality in *The Nature of Things* could be, 'why did so many very different people fall in love with Crystallography?' This begs further questions about the nature of Crystallography. Is it a science, an art, a community, a religion, a movement, a family, the springboard for a communist revolution, the catalyst for a technological revolution, a love affair, a way of understanding ourselves/the world, a route to recognition, a life saving pharmaceutical/medical tool or just a success story for women?

I originally wanted to research three female scientists (rather than one) because I thought it would help represent differences amongst the unusually large proportion of women in Crystallography. I wanted to explore the themes of the play through a common dramatic action relating to the requirements for a woman to succeed as a

first class scientist. The activities of science at home and bringing the home into the lab came directly from the research, which highlighted the extraordinary group camaraderie and acceptance that they might seem ‘a little peculiar’.

Of course *what* Crystallography is, is inextricably connected to *how* the characters and audience experience it through the course of the play. The profound interdependence of form, content, results and process goes right to the heart of *The Nature of Things.* The dramatisation of the process of discovery resonates on both the scientific and human levels. This works through photographs, examinations, experiments and models of crystals as well as people. Teresa’s portrait of Crystallography is also a model of Crystallographers. The development of this central image echoes the narrative of the play as an extended metaphor.

The same connections can be traced back to Bernal (1964) who said that Dorothy ‘was one of these masters whose method of work is as exciting and beautiful to follow as the results that flow from it.’ (cited in Nobel, 1994)

Before leaving this comparison with *Copenhagen* it is important to note the purely functional role of Margrethe and Teresa as non-scientists. During the play other non-scientists in the audience can identify with them as they go through a similar learning experience. This device justifies explanations of the science using simple terminology and accessible imagery that explicitly connects with the dance. This greatly helps to make the science comprehensible and so ensure that every audience member is on the same page. As Teresa was the last major character I wrote to join the play, I might still be able to improve on her character’s language and idiom. In the submitted script her process of learning means that she lives in the present. Her associated

childish clear objectives and reactions help achieve a scene's purpose very quickly but occasionally this might be at the expense of creating a fully formed character.

Communicating Facts - Scientific Learning and Verbatim Stories

An alternative route to a science play is where the stage is the new attractive proposition as a highly effective medium to communicate scientific ideas or relate verbatim stories. The chemistry professor Carl Djerassi (*Newton's Whores, Oxygen, An Immaculate Misconception*) and biographer Georgina Ferry (2010) (*Hidden Glory: Dorothy Hodgkin in her own words*) are prime examples of a scientist and science history writer turned playwright.

Carl Djerassi's work represents a rare breed of plays, outside theatre in education, which prioritise 'learning something while being entertained'. He uses 'drama to smuggle important information generally not available on the stage into the minds of a general public' (2002, p.193). My intentions are aligned with Djerassi's to a certain extent on the proviso that doing this reinforces the main contention of the play. I like the idea of aiming the play at a general audience and also not simplifying the ideas. This requires careful selection and imaginative communication of the pertinent science. Exposition is doubly difficult for a science playwright because there is the task of expressing relatively complex ideas as well as the information necessary to tell the story. Wherever possible I avoided the usual sorts of exposition by moving to different points in time and letting events play out in the present. I continually tried to reduce the number of words for all exposition and I could probably still improve on

this. My main method of ‘smuggling’ exposition in was by ensuring there is always a situational pressure such as the potential to achieve something deeply desired. This keeps the stakes high and so buys expositional time. In 1.4 Kathleen gets a lot of information across whilst trying to conquer her nerves, impress Bragg and so pass what she thinks is an oral examination for her degree:

> - the way the molecule organises itself into a stackable unit – how lots of these units pack up to make a crystal. Can I start again?

Here Kathleen’s emotional state can be conveyed through relatively dry text. Feedback from the workshop performance of *The Nature of Things* emphasised that the scientists’ passion for their subject became infectious. One audience member proposed that if the work encouraged someone to find out more for their own interest then that would be a good measure of success.

Pitching any explanations at the right level is always a delicate balancing act. Michael Blakemore (2000), the original director of Copenhagen believes that an audience doesn’t need ‘to comprehensively understand the science, but they need to understand it moment by moment as they hear it.’ In *The Nature of Things* I attempted to deliver the science in digestible chunks that enhance the drama and add up to something fairly sophisticated by the end of the play. Using other media significantly relieved the burden of exposition on the text.

Hidden Glory is the only play about Dorothy Hodgkin other than *The Nature of Things* that I am aware of. It entirely consists of Dorothy’s own words which Georgina Ferry has shaped into a monologue. This elegant, simple and respectful treatment of the

source material invites audiences to really listen to all the gentle nuances of expression that intimate Dorothy's thoughts. Despite the common criticism that scientists are bad at communicating, Dorothy's many letters, speeches and papers show that she is quite clearly an exception. There can be something magical and powerful about hearing the original words of a real life character on stage whether this is only the case if listeners are aware of the script's authentic origins or because it contains a kernel of 'truth' is hard to say. It is arguably the most direct method of accessing a character's thoughts and feelings.

There is now a great deal of poetic spoken and written source material in the public domain by many of the characters in my play, often to and about each other, as well as about the science itself. Francis Crick is no exception:

> Unlike a great work of art or the jet engine which had to be invented, the DNA structure was always there. I was just lucky to be involved in the painting of its first picture. (2.2)

I consciously tried not to give the scientists' text any special treatment over my own and had to be just as brutal about its inclusion. Reading their work, as well as hearing and watching recordings of live interviews helped me to attempt to develop some fluency and credibility when inventing characters' speech and behaviour. Their use of language reflects their logic, speed of thought, self-awareness and way they consider or seek to affect others. The video interview with Guy Dodson and a rather frail looking Dorothy aged eighty has greatly informed the way I chose to present her.

Reports of the way other people perceived the scientists has also been extremely informative. The classic thing many crystallographers like Guy Dodson have recounted about Dorothy's behaviour in the lab is how she tended to phrase advice in inoffensive structures like 'it might be an idea to try...' Yet Dodson also insists 'it was understood that the soft nature of her remarks should not be misinterpreted – this was advice to be followed!' (2002, p.13) I was hugely intrigued about how Dorothy managed this contradiction. How did people realise that she was made of more formidable stuff underneath her gentle exterior? How would it manifest itself in the interaction with an unpredictable personality like Teresa in the art college (instead of a lab) where Dorothy's status would be unclear? I imagined that ideally Dorothy would have preferred to pass her work on to a scientist to continue the art of Crystallography. So it is with gratitude and resentment that she hands over her life's work to Teresa and becomes increasingly aware that she has commissioned a portrait of history.

It became apparent fairly early on that I was interested in investigating the way my chosen characters interacted with each other by placing them in situations and using dialogue rather than pure monologues. My piece covers a much wider scope than Georgina Ferry's. It is certainly also far looser with facts, whilst preserving an emotional truth through the hidden impetus for each scene. Embedding the original words in a fictional framework creates the possibility of immediate drama. One example of this is Dorothy's confession at the end of the play:

> I used to say that the evening I developed the first X-ray photograph I took of insulin was the most exciting moment of my life. But the Saturday afternoon,

> when we realised that the insulin electron density map was interpretable, runs that moment very close. (2.2)

Due to the way this invented scene has been set up, this statement not only informs us about Dorothy's deep emotional investment in her work, but by using the word 'we' it lays the first concrete clue for Teresa that Dorothy was in fact closely involved, if not central, to the final stages of solving insulin. Up until this moment Dorothy has deliberately wrong footed Teresa by describing the events as an outsider at a distance from the final insulin group.

Interdisciplinary Collaboration

So far I have looked at plays by playwrights and scientists working separately. An alternative way to make a science play is the collaboration between a writer/director, a scientist and company of performers. Notable partnerships include Mick Gordon and Paul Broks *(On Ego* – On Theatre), Peter Brook and Marie-Helene Estienne (*The Man Who*), Simon McBurney and Marcus du Sautoy (*A Disappearing Number* – Complicite), Luca Ronconi and John Barrow (*Infinities*), Wayne McGregor and Philip Barnard with David Kirsch (*Far*- Random Dance). These collaborations have tended to give *ideas* equal status if not greater importance than *people*. The list is arranged in an order that becomes progressively less text based and more physical to include acrobatics and ultimately pure dance and so perhaps would suggest that movement, design and performance games often offer a far more powerful, accurate and playful translation of scientific ideas than lengthy text.

The main attraction for my choosing the science of Crystallography was the potential

for the rules behind the beautiful repeating patterns and complex symmetries of molecular crystal structures to provide an incredibly fertile stimulus for dance, design and games. Crystallography patterns have already been successfully exploited for their aesthetic appeal to interest non-scientists during the 1951 *Festival of Britain* exhibition (Jardine, 2010) and more recently the *Atoms to Patterns* exhibition at the Wellcome Trust (Jackson, 2008). The double helical structure of DNA has made a huge impact on art, so much so that it is one of the few molecular structures well known to the general public. I would venture that its elegant image is far more famous than any of the scientists who discovered it. To assign the movement and design concrete intellectual meaning and endow it with emotional significance requires careful integration of textual references and setting up some sort of situation. In dance, rhythm, dynamics, physical clowning, sheer athleticism and artistic excellence can certainly generate theatrical emotional journeys, but to ensure that a wide target audience engages with the content of a piece of theatre, I would still argue that the most effective strategy is simply telling a compelling human story. In the interdisciplinary workshop performance of *The Nature of Things* the audience identified the comedy and dance as the two components they enjoyed most. The actor Jack Klaff agreed:

> I loved the fact that the people were human, quirky and funny. Real… Dancing's good, symbols are good, ethereal is good, but all of that was made better for me when it was undercut, when something Arty happened which was slightly teased, when it was a little self-deprecating, cheeky, gritty, fun. That made the beauty more beautiful. (Berrigan et al, 2010)

One moment in the performance that illustrates this point particularly well was when the actress playing Kathleen, who describes herself as ‘physically rubbish’, tried to learn the science by copying the dancers movement. The moment when she achieved unison with him in 1.7 was both funny and moving.

An extremely useful suggestion that came out of that performance was to give the dancer’s physical actions stronger dramatic consequences. One moment in the submitted script that I think achieves this is at the end of 2.1. When Watson reaches for the DNA performer, Rosalind charges at Watson to protect DNA from him and in so doing terrifies him into fleeing the room.

Ideas and people necessarily coexist in theatre. Even if one is merely used to serve the other, it cannot be obliterated. In *Infinities*, the director Ronconi (Bologna, 2006) deliberately elevates abstract ideas by operating in a dreamlike space where the normal rules of human interaction don’t apply. Ironically this liberation often leads to visceral and intensely moving human moments. I adopted a literal dream state for the very end of Act 1 in *The Nature of Things.* The rules that have been established up to that point in the play are suddenly freed up and inverted once the male science dancer’s behaviour transforms him into a tender human-like lover in Dorothy’s dream. Further exchanges and events within the dream are compressed to their raw emotional essence. As Dorothy was unlikely to divulge any personal concerns to Teresa within the play’s ‘real’ world, especially at this relatively early stage in their relationship, using the crucible of a dream seemed the only way to expose the intensity of Dorothy’s true feelings. This revelatory departure helps raise the stakes cumulatively through the threat of losing the insulin crystals, the dangers of

impending war, the potential starvation of a new-born who won't feed and the sudden increased severity of Dorothy's crippling arthritis. Meanwhile in the real world, Teresa opens the book that began Dorothy's obsession with insulin and reminds us that diabetes was a death sentence, just in time for the first act closer.

Even outside this extreme episode, my play can be described as a love story between a scientist and her subject. This is especially true of Dorothy's feelings towards her insulin work. In the play the unique world of each scientist's imagination has a very specific ecology of ideas and experiences that live and evolve there. They are deeply romantic places. Peter Brook reached a similar conclusion when working on *The Man Who*:

> Seen in this way, science certainly becomes "romantic", and the inner landscapes of the brain do indeed suggest what in another mythology – the Persian Poem The Conference of Birds – is called the "Valley of Astonishment" (1968) (cited in Shepherd-Barr, 2006, p. 179)

In *The Nature of Things* 'redirecting the imagination' is crucial to achieving the elusive breakthrough of 'seeing' the science patterns performed by the dancers. It is the great challenge in the play intended to hook all the characters and audience alike. The required shift in focus is designed to 'click' at different times for different people on different levels, rather like the moment when a 'magic eye' picture suddenly transforms into something meaningful and recognisable. It is something people crave and understandably become obsessed by. The first time that Teresa transforms into Rosalind and glimpses the DNA performer in 2.1 she is instantly

infatuated. However this process is a two-way exchange between the science and scientist where the science may misbehave.

Although this method of investigating a scientist's relationship to their work is unconventional, it still qualifies as a human story. So returning to the assumption that compelling human stories are useful in attracting a wide target audience, is it better to stick rigidly to a biographical story or create an entirely fictional narrative? An advantage of biographical characters is the unpredictability that real life throws into the mix. Shepherd-Barr contends that 'such figures are irresistible partly because of their authenticity, and because of the liberating quality of their often unconventional behaviour' (2006, p. 54). The science too adds a certain amount of controlled unpredictability:

> A great advantage of X-ray analysis as a method of chemical structure analysis is its power to show some totally unexpected and surprising structure with, at the same time, complete certainty. (Hodgkin, 1964b, p.83)

According to Aristotle, drama is 'heightened when things happen unexpectedly as well as logically, for then they will be more remarkable than if they seem merely mechanical or accidental' (1965, p.45). Therefore in theory, cleverly crafting a logical journey for a biographical character has the potential to achieve a good balance of chaos and order.

The disadvantages of using biographical stories include: the enormous amount of research required; the responsibility to discover 'the truth' over which you have limited control; the pressure to convey 'the truth' or face certain criticism; the difficult

task of selecting events; grasping the essence/contradictions of a personality and essentially condensing an entire life (or as in *The Nature of Things* many lives) to a suitable story for a time limited piece of theatre.

Another consideration when using a real scientist as a protagonist is that relatively few scientists are well known by the general public. This means you cannot assume that the audience has any special prior knowledge or expectations about them. In this sense they will be received by an audience in the same way as any fictional character. The public know very little indeed about Kathleen Lonsdale even though she was one of the first Crystallography pioneers and first woman elected to the Royal Society. I found I couldn't tell Dorothy's story without including hers. The same is true of John Desmond Bernal (Sage).

The play *A Disappearing Number* uses both biographical and fictional characters. The two main storylines operate on a double timescale following a biographical relationship in the past and a fictional one in the present. The two stories are connected by the science. This structure gives the play an epic universality and modern relevance, which is something I have tried to emulate in *The Nature of Things*.

Overview and Implications

The different approaches of playwrights, scientists and collaborators in creating a science play reflect a range of reasons that might attract a theatremaker to explore a scientific idea and/or real lives. The broad spectrum of tastes and priorities have tangible repercussions on the work that results. This illustrates the current state of

affairs regarding the gap between science and art which C. P. Snow (1993) refers to as the ‘two cultures’ in his book of the same title. One might expect that all science plays should serve to bridge this gap. However in any interdisciplinary undertaking each component essentially competes for the highest place in a class system in which no one likes to be subordinate.

Just looking at the selection of works mentioned above it would appear that the science play’s potential core ingredients of

science, history, biography, fiction, narrative, traditional drama, surreal dreams, memory plays, time travel, comedy, text, dance and design/digital media

vie for centre stage coupled with the intentions of creating

an immediate experience, an intellectual debate, a dazzling spectacle, an art installation, an experiment, a puzzle, education, aesthetic beauty, romance, authenticity, unpredictability, excavating the ‘facts’, telling a good story, telling the ‘truth’, humanising scientists, expressing patterns, entertainment, emotional catharsis, provoking personal reflection, challenging accepted beliefs, adding to our cultural heritage and public consciousness, pushing the boundaries of theatre practice, exciting imagination and finding a common humanity.

As I have both a science and arts background, my thinking, practice and preferences fall somewhere in the middle of the ‘two cultures’. There will always be a tension between a playwright’s obligation to distil biography, history and science accurately and also fulfil an artistic duty to themselves, as well as their audience hence compromises are inevitable. In fact imposing these conflicting restrictions is essential

to finding innovative solutions to impossibly ambitious theatre experiments. To satisfy all these basic parameters demands brutal decisions about the inclusion and treatment of the terrifyingly vast possible interpretations of the raw subject matter on stage. I felt that the basic requirement was for both the science and real human stories to be rigorously embedded in the structure of the play and also central to its dramatic drive. In order to achieve this I realised that drama would be my primary theatrical medium closely supported by dance and then design/digital media. Glynne Wickam, a contemporary of C. P. Snow, explains why drama has the potential to bridge the 'two cultures':

> [Drama has an] integrating power, a subject which can relate the ancient world to the present day, which can bring critical appraisal into direct contact with creative experiment, which can provide the arts man with a lively introduction to scientific thinking and the scientist with a lively reflection of his own human condition. (1962) (cited in Shepherd-Barr, 2006, p. 13)

Conclusion

My ultimate aim for *The Nature of Things* therefore is to make a contribution as a rigorously researched 'science play' capitalising on the wealth of theatrical strategies available balanced in a coherent dramatic experience that relates the story of Dorothy Hodgkin and Crystallography. Through this my primary intention is simply to create an enjoyable piece of interdisciplinary theatre.

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The Nature of Things – the play

THE NATURE OF THINGS

Characters

If necessary doubling is possible with a cast of 3 female actors, 3 male actors and 3 dancers (including at least 1 male and 1 female dancer)

Dorothy Crowfoot Hodgkin (*Dotty* – 80 years old but regresses)

Teresa (early twenties), **Rosalind Franklin** (starts 31, ends 38, clipped 1950s upper class RP)

Male Science Performer – MSP, Doctor, the King of Sweden

Sir William Bragg (starts 59), **Sir Lawrence Bragg** (62, son of Sir William)

Kathleen Yardley Lonsdale (starts 18, ends 48, almost 7 years older than Dorothy)

Female Science Performer – FSP, Nurse, the Queen of Sweden

Thomas Lonsdale (Yorkshireman, 4 years older than Kathleen)

Sage – John Desmond Bernal (Mad hair and huge head, RP but slips into Irish if swearing, 2 years older than Kathleen but joined the Royal Institution just after her)

James Watson (starts 23 - American/loves tennis)

Maurice Wilkins (starts 35, painfully shy/proper/awkward)

Francis Crick (starts 35, loud laugh and clothes)

Professor G. Hägg (Swedish)

Professor A. Engström (Swedish) – combine this role with Hägg if doubling permits

Max Perutz (Jewish from Vienna, 4 years younger than Dorothy)

Smaller roles: **John Kendrew, Journalist 1, Journalist 2**

Act 1.

Scene 1 Teresa's area of the Art College, top floor, Friday evening, March **1990.**

Teresa is frantically trying to scrub out a stain on a large hammock. The whirr from the lift gets louder and the lit 'up' arrow flashes. Teresa strategically places a battered cuddly toy on top of the stain. She then clocks several strewn empty cigarette packets and a litre water bottle containing a build up of cigarettes and arranges them artily around the hammock. The lift opens. Dorothy emerges in a wheelchair.

Teresa Stay natural.

Dorothy Oh golly.

Teresa takes a Polaroid photograph of Dorothy.

Teresa Nice dress.

Dorothy Thank you.

Teresa Is it vintage?

Dorothy Everything I own is vintage. Drafty isn't it?

Teresa Would you like my coat?

Dorothy clocks the hammock/cigarettes.

Dorothy Smoking outside must mean a fair old trek. Do you know how old it is?.. The building?

Teresa No idea.

Dorothy I suppose this is your common area?

Teresa Everyone knows it's my area.

Dorothy Do they?

Teresa No one will interrupt us. Plus the building's mostly empty once the weekend starts.

Dorothy's attention turns back to the hammock.

Teresa *[Distracting Dorothy with the fresh Polaroid]* Whoa! You look - excited.

Dorothy *[Examining the photo]* Oh golly! Excited or electrocuted?

Teresa I'm excited – pleased you've come.

Dorothy I convinced my daughter to send me up alone.

Teresa Look at the photo again. What's your first reaction to seeing yourself? - You today. What isn't there?

Awkward silence as Dorothy tries to think but fails to ignore the hammock.

I call it 'My Hammock'.

Dorothy Oh you sleep here?

Teresa It's my self-portrait.

Dorothy Of course.

Teresa Stretched like my shell. Revealing my

Dorothy patterns.

Teresa habits. Containing my skin, my sweat,

Dorothy Your teddy.

Teresa infected with concentrated germs-

Dorothy poor teddy

Teresa –of emotional truth. Stains of truth! Why does saying the word 'truth' make everything sound like a lie?

Dorothy Yes. *[Inspecting the hammock]* Yes.

Teresa It's probably before it's time.

Dorothy Start the work and pray that someone will want to catch up with you.

Teresa Do you want me to start work? The biggest challenge I can imagine would be the portrait of another artist. A true artist.

Dorothy Oh I- Oh. I am not an artist.

Teresa What? Yeah you are. You know loads about photography and mosaics. Oh right – does it have some special name – what you do?

Dorothy Yes, but I'm afraid it really isn't an art.

Teresa Ok, so why was everyone at the unveiling in awe of you?

Dorothy I rather expect it was the portrait they admired. The fourth and last attempt on my life I hope.

Teresa You're joking?!

Dorothy Executed brilliantly of course.

Teresa You've changed your mind then?

Dorothy I don't believe so.

Teresa I thought you wanted to commission a new portrait?

Dorothy I want an accurate portrayal of my subject, my field.

Teresa I'm all about accuracy.

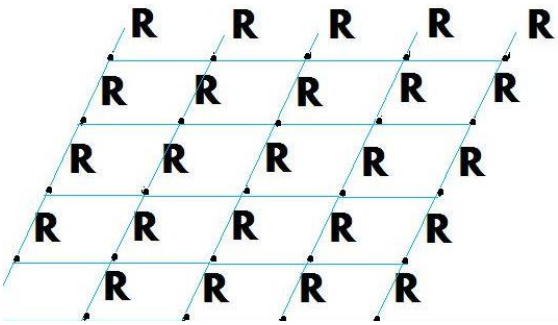
Dorothy You thought I was an artist.

Teresa What would you think?! *[reading Dorothy's portrait description from a postcard – Teresa isn't the most confident reader!]* "Dorothy Hodgkin is our greatest ambassador in invisible worlds. Through her work, we 'see further'."

Scene 2 An auditorium. Bedford College for women. University of London. **1921.**

The male science performer (MSP) plays/clowns with the audience's expectations by striking a simple asymmetric pose (e.g. a lunge) at chosen points within a 3D lattice.

Bragg's voice So as you see, a crystal has many repeating units, stacked beside each other. Each unit contains an identical asymmetric shape - a cluster of atoms making up a molecule, which we will refer to for now as 'R'.



Bragg's voice puppeteers MSP's movement. Success is hitting the next 'R' pose in the lattice just as Bragg says 'R'. Must MSP lose rigour or even cheat to succeed?

So we have R. Followed by.. R. R and R.. Then R *[new row]* R.. R.. R.. R and so on.

R repeats at all points in the crystal lattice. *[breather]* All of them. *[continue]* Why go to all the trouble of making a crystal? Anyone?

Kathleen The patterns.

Bragg Yes?

Kathleen *[from the auditorium seats]* They can be so beautiful – the symmetry, the order, the subtleties. I sound like a typical woman now don't I?

Bragg Give it a few more years perhaps.

Kathleen I would like to be a scientist.

Bragg Someone else? - Why make a crystal?

Kathleen To discover the secrets of an elusive molecule.

Bragg And what would happen if you just fired X-rays at a poor lonely isolated molecule instead? One R on its own?

Kathleen The X-rays would probably pass straight through it.

Bragg Correct.

Kathleen At best they'd scatter undetectably.

Bragg And at worst?

Kathleen I suppose they could destroy the molecule leaving nothing to experiment on at all! Devastating. Disaster.

Bragg Do come down.

Kathleen makes her way to the stage.

How would you like the molecules arranged in your crystal?

Kathleen Mine?!

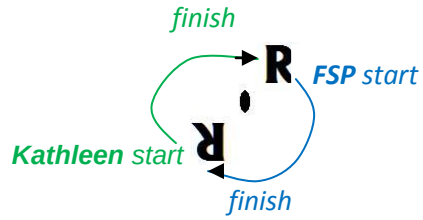
Bragg Choose a design. Something with symmetry.

Kathleen Well, perhaps it could be *[pronounced 'R R' though MSP refuses to dance for Kathleen]* R R . R- ***[MSP SPITS AT KATHLEEN]***

Bragg I can't see it. What do you mean exactly?

MSP leads slow foot stomping in the auditorium to undermine Kathleen. A Female Science Performer (FSP) joins Kathleen to dance out her design and defy MSP.

Kathleen



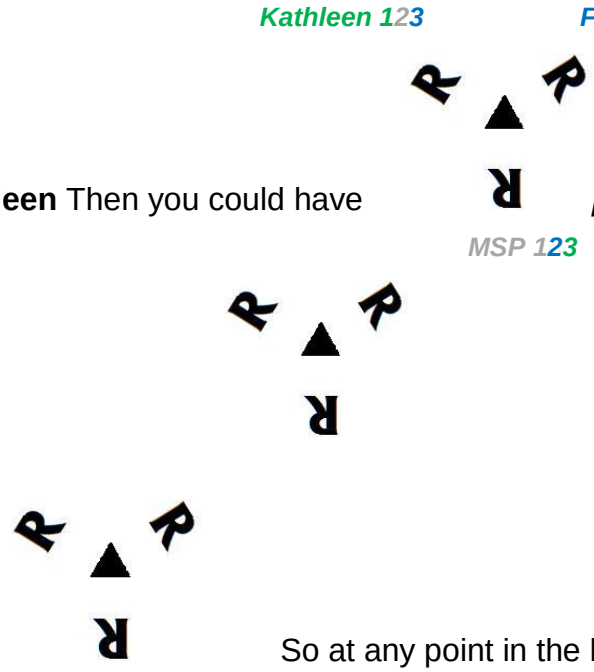
R
R
R
R
R
R

and so on.

Stomping cuts out on waiting to hear Bragg's verdict.

Bragg Precisely.

MSP becomes swept up in the new dance:



Kathleen Then you could have *[pronounced 'RRR']*

So at any point in the lattice, I always see the same pattern repeated in front of me and behind me. Rather like being lost in the forest where everything looks the same in all directions.

Bragg Is there a Hansel in the auditorium for this young lady's Gretel? Who will lead us safely through these dark and thorny woods?

Scene 3 Back at the Art College Friday evening

Teresa I hate science.

Dorothy You look like a scientist.

Teresa My science teacher was a right wanker. What? What do you mean I look like a scientist?!

Dorothy One scientist particularly.

Teresa Besides my parents it's probably the thing I hate most in the world.

Dorothy *[Preparing to leave]* Well it was nice to have met you.

Teresa How much would you pay?

Dorothy You don't think it might make a good coursework project?

Teresa Not really.

Dorothy Why not? Why did you become an artist?

Teresa Because I'm good. I could always do good likenesses.

Dorothy And that gives you pleasure?

Teresa Course. When I was a kid. Like an obsession. Every detail in place. Then you can start to bring out what really matters by accentuating things, exaggerating things, leading the eye to the real picture. You have to see it first, you have to get it. You think and sketch for days and then somehow it comes out, it clicks like a surprise adding up to much more than you realised.

Dorothy It sounds like you must have had a wonderful art teacher?

Teresa Not really.. She liked that I made her look good.

Dorothy So you did well at school then?

Teresa Not really.

Dorothy Not in art?

Teresa In art I was awesome. I did ten A levels.

Dorothy Ten! All in art?

Teresa My class paid me well.. The students here used to pay me well too – for their coursework projects.

Dorothy But they don't anymore?

Teresa Some would - but now they're too scared.

Dorothy If I could get some money, what will you spend it on?

Teresa That's a question for a child not an artist. I'd buy my parents' council flat.

Dorothy Lovely idea – of course I couldn't

Teresa Then throw them out. Teach them a lesson for scrounging off the back of my birth.

Dorothy You were the one getting thrown out at the unveiling.

Teresa Til you stepped in and saved me. I want to work. Why else would I gatecrash something like that? You knew I wasn't meant to be there straight off.

Dorothy Did I?

Teresa Yeah you gave me this conspirator-like wink. Really funny – in a good way. Really nice.

Dorothy So you want to work but not on a piece like mine.

Teresa Why shouldn't I earn proper money from art?

Dorothy Ah! You will do the piece for the right money!

Teresa I work hard. I push the boundaries of working hard.

Dorothy You certainly push.

Teresa You could have asked any major artist yesterday but you chose me because you get that my work is- *[realising]* Oh my God, I'm so stupid.

Dorothy Teresa?

Teresa You didn't choose me because you think I'm good, you chose me because you think a student will be cheap.

Dorothy This is important. It needs meticulous imagination.

Teresa What is 'it' exactly? – a portrait of?

Dorothy Crystallography.

Teresa I don't think so. *[i.e. I'm not doing it]* Portraits are of people. Life. Being alive.

Dorothy I'll find you some money.

Teresa Only if you're at the centre of the piece.

Dorothy Don't you dare put me on a pedestal!

Teresa Take it or leave it.

Dorothy Perhaps I could be central but invisible.

Teresa Nope.

Dorothy Why?

Teresa Don't try and trick me. You're my only way in. I could get you, you know, if you let me.

Dorothy I was just lucky to have fallen in with a group of pioneers. At most I'm a piece of the puzzle. As are a great many people. And crystals.

Teresa Crystals?!

Dorothy Molecules.

Teresa I can't make a portrait of something I can't f-ing see can I? Or touch at least. Or get. Or like.

Dorothy Start first and then decide.

Teresa Jesus, how the hell! How did you start?

Dorothy When I was eleven, my mother allowed me to set up my own chemistry experiments in our attic. Then one Christmas-

Sudden lighting change as magical music transports us to Dorothy's attic 1924. *Young Dorothy is kneeling on the floor, unwrapping a parcel in brown paper.*

Teresa *[shocked at seeing Dorothy on the floor]* Oh my God!

Teresa disappears from view as we focus on Dorothy's experience.

Dorothy *[reading]* 'Concerning the Nature of Things'. By Sir William Bragg.

FSP emerges and dances out the book's scientific concepts in Dorothy's peripheral vision – she is drawn to Dorothy and Dorothy to her but they are also both influenced by the book, producing moments of distance/elasticity and also moments when they almost touch.

Dorothy cannot see FSP yet.

Bragg's voice Broadly speaking, the discovery of X-rays has increased the keenness of our vision a thousand times, and we can now 'see' individual atoms and molecules.

Dorothy It's from my mother.

Bragg's voice We have been given, so to speak, new eyes.

Teresa's voice *[Disturbed by Dorothy's movement]* Dorothy!

Bragg's voice We can look far down into the structure of solid bodies, and observe in detail the design of their composition.

Dorothy To understand why things are the way they are

Teresa's voice *[Alarmed by Dorothy's attempt to stand up]* Oh my God.

Dorothy and exactly how they function,

Teresa's voice Be careful!

Dorothy you can break them down to the tiniest level of detail and find out how all the pieces fit together.

Dorothy opens the 2nd book laid in her path by FSP.

Dorothy *[reading]* Fundamentals of Biochemistry-

Dorothy flicks through the book and is suddenly physically appalled/stunned by what she sees on the page.

Teresa's voice What's wrong?

Bragg's voice For thousands of years diabetes has been a death sentence.

Teresa *[Rushing to check on Dorothy then suddenly taken aback at seeing the picture on the page.]* Oh Jesus!

Attic partial setting cuts out and FSP disappears. Dorothy is on the verge of falling.

Oh God! Dorothy!

[Teresa catches Dorothy and negotiates getting her back in the wheelchair] Are you alright?

Dorothy Of course.

Teresa You lost it. You left your chair.

Dorothy Did I?

Teresa Don't do it again! Jesus! Do you mind if I smoke?

Dorothy I'd rather you didn't.

Teresa Who was that child in the book? You turned the page and he looked -

Dorothy I'm sorry it upset you.

Teresa - like one of those Romanian orphans.

Dorothy He has diabetes.

Teresa A starving skeleton.

Dorothy Diabetes *is* starvation if your body is forced to eat away at itself.

Teresa It's not a death sentence. It's not AIDs.

Dorothy Diagnosis usually meant three weeks to live at best.

Teresa Shit.. Do you think someone's personality can be like a death sentence. Like there's no way they'll last that long.. How old are you? Shit forget that.

Dorothy Eighty.

Teresa Wow. Well done. Seriously. I don't think I could make it half as long.

Dorothy You're not ill are you?

Teresa Maybe. In trouble maybe.

Dorothy Financially?

Teresa Oh fuck that. I'll be alright I'm sure.

Teresa gets out a cigarette and plays with it.

Dorothy Where do you live Teresa?

Teresa Don't start.

Teresa puts the cigarette to her mouth – unlit.

Dorothy Teresa?

Teresa Everywhere. Longest place I stayed was in South Ken.

Dorothy Really?!

Teresa Really. With this posh numskull on my course. I don't live there anymore.

Dorothy Pity.

Teresa Not really. We were all sitting around at lunch and the numskull said something so stupid about only gay blokes having AIDs. This college is full of gay blokes. So I said I found that really offensive because I have HIV.

Dorothy I see. Is that why you don't live in South Kensington anymore?

Teresa No, that's when she asked me to move in. I looked a right state because I crash on peoples' couches when I help them with their art but I don't sleep that much.

Dorothy You must be entitled to a maintenance grant.

Teresa Oh no, my parents' dodgy paperwork screwed that right up.

Dorothy What about a loan?

Teresa As if I'd ever be able to pay it back. As if I'd want to.

Dorothy But you lived with this girl in South Kensington for a time.

Teresa Yeah she gave me loads of awesome clothes and food and skin treatments. She watched everything I did really closely for about a year. I was her personal project. I was starting to look really good – really healthy.

Dorothy It sounds quite splendid.

Teresa She was changing me.

Dorothy Not helping you?

Teresa And copying me. She's an amazing mimic. She had every superficial detail down. She presented me, her version of me, as a performance - her big project. She wouldn't tell anyone what it was. Not even our tutor. He was getting really aggravated about it because she kept delaying it. 'It isn't the right time yet'. Then he forced her to do it anyway. Everyone thought the likeness to me was spot on – I'll give her that.

Dorothy Perhaps you should be flattered.

Teresa I ruined it for her.

Dorothy I'm sure you didn't. How could you?

Teresa By breathing. By being there – here. Still. Amazingly. I robbed her piece of the power it should have had. She was counting on me, the greatest friend she would have ever have had if I'd only behaved as I was supposed to and ignited her career.

Dorothy I'm sorry Teresa you'll have to explain. You couldn't have done her work for her on this occasion could you? You would never get away with pretending to be her being you. And there isn't any skill in just being yourself either is there - I mean that she could take credit for.

Teresa Oh no she definitely wanted to play me herself - me the numskull's best friend with HIV. But I properly screwed it up for her because I didn't die in time. She was counting on me dying, for depth. Straight after her presentation she asked me to say a few words, desperate for me to be profound.. I thanked her for raping my identity. I confessed that actually I didn't have HIV as far as I knew. That actually I'd lied that lunchtime as a reflex reaction to her stupid remark. And that I was genuinely sad to lose her as an imaginary friend but glad to gain some weight and designer clothes. You should know now I can get a bit mouthy when I'm wound up. It's kindof a compliment.

Dorothy What did you do for *your* big project?

Teresa A performance piece. The numskull had inspired me into 'being myself' I think. It was just me as myself sleeping in the hammock.

Dorothy With your teddy?

Teresa Nope. No teddy then. I knocked myself out completely with sleeping pills every day for five days and invited people to express themselves – to do whatever they wanted to me. Anything, I didn't care. I don't care because I care about the work.

Dorothy Golly.

Teresa If art really makes people think and feel and get something it's totally worth risking a bit. You have to commit. Even if the viewers are complete morons.

Dorothy What did you want people to take from your piece?

Teresa Anything. Something they're missing. Empathy maybe. Definitely empathy. It wasn't about my ego it was about them. I don't like being at the centre of things either, but if that's what's got everyone's attention for whatever reason then it makes sense to accept that that's the way in. It made sense to go with it.

Dorothy I'm truly not being precious Teresa.

Teresa Teri.

Dorothy You certainly suffer for your art Teri.

Teresa Not really.

Silence.

Dorothy Alright, use me as a way in. Just as a way to see.

Teresa Awesome. Alright – don't think – Say three things that have shaped your life. Quick.

Dorothy Seeing crystals. My parents, my husband. That book. The two books really.

Teresa You mean with that picture? The boy with diabetes?

Dorothy Yes that chapter particularly.

Teresa How old were you?

Dorothy Eleven perhaps. Yes. A group of Canadian scientists injected a dying teenager with ‘a mysterious something’. A miracle. Insulin didn’t have a proper name yet.

Teresa They cured a teenager.

Dorothy Treated not cured.

Teresa Same difference.

Dorothy If you stop giving insulin to a type one diabetic you will kill them. So they keep on injecting.

Teresa *What* do they inject? Where did the miracle come from?

Dorothy Dogs initially. They tied up their pancreas’ and

Teresa killed dogs?

Dorothy They moved on to grinding up a beef pancreas which

Teresa killed a cow?

Dorothy Suddenly there was demand all around the world. Very quickly an insulin famine hit.

Teresa they ran out of cows and dogs?!

Dorothy They failed to replicate the exact recipe for preparing the pancreas extracts. A young girl they had treated couldn’t wait for the scientists to rediscover their experiment so

Teresa They killed a girl.

Dorothy Despite one's best intentions medicine is often far more dangerous than art.

Teresa *[Deliberately provocative]* Don't take risks then.

Dorothy Hundreds of diabetics were swarming and camping at the doors of the labs trying to get at any insulin at all.

Teresa Coz they fucked up. Doctors always fuck up.

Dorothy Stumbling in the dark, as we all did, you try anything in case it works.

Teresa Shouldn't you scientists follow a proper procedure?

Dorothy They *made* the procedure. Finally their miracle was mass produced. Diabetics tried to cope with any poisonous impurities in the treatment – sometimes they built up resistance to the insulin itself.

Teresa So? *[Realising]* They died anyway.

Maybe molecules should be my new medium. Molecular art! I'm not killing any dogs!

Dorothy Once you know every detail of a molecule's structure you can synthesise it entirely out of other chemicals.

Teresa Battersea must have been relieved – the dog's home.

Dorothy Teresa.

Teresa What's insulin's structure then?

Dorothy My raison d'etre.

Teresa Your what?

Dorothy It's a protein. All proteins look something like that.

Teresa My breasts?

Dorothy Your beads.

Teresa takes off her beads. FSP begins dancing.

Long necklace-like backbones folded up into strange shapes - decorated with exotic side chains.

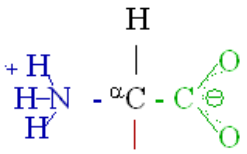
Teresa Insulin is a necklace?!

Dorothy No one knew which beads were in insulin or how they were arranged. But I thought there must be a way to work it out.

Teresa Why *must* there?

Dorothy There are only ever twenty types of bead to include. All identical, except a characteristic side chain made from atoms.

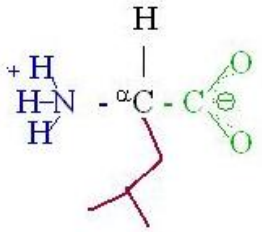
FSP snatches Dorothy's book and dances different amino acid/bead structures. Teresa gets her head down and sketches them furiously with Dorothy's guidance as Dorothy senses FSP, her muse:



Small. Oily.

Drop.

Glycine!

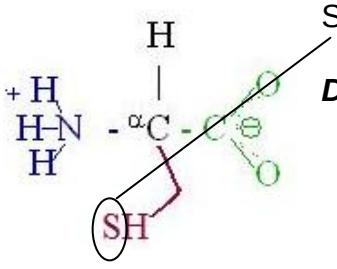


Branch. Branch.

Branch and

branch! Leucine!

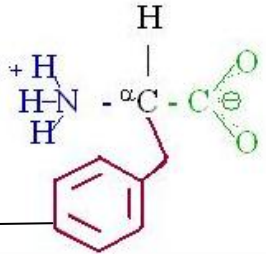
Dorothy sneaks out of her chair transforming into the young girl in search of FSP.



Sulphurous. ***FSP leaps onto Dorothy.*** Highly reactive.

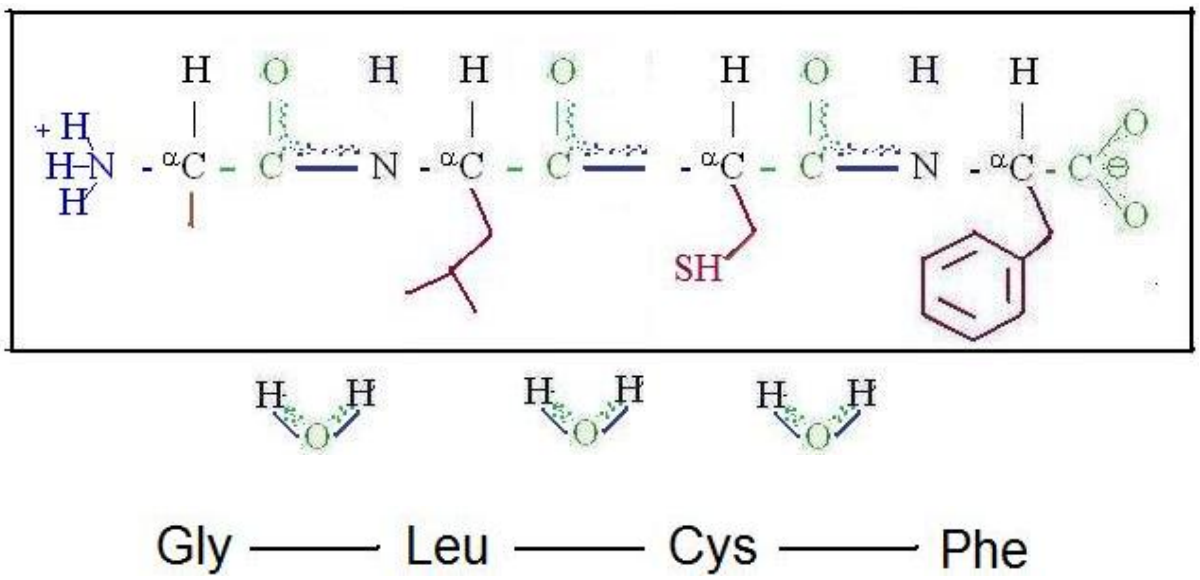
Dorothy sees/speaks to FSP directly. Cysteine!

Dorothy double takes at the shock realisation of seeing FSP for the first time! ***FSP circles Dorothy.***



A ring! Phenylalanine.

Teresa So if I put these beads *[from her necklace]* together to link say glycine *[FSP drops]* to leucine *[FSP branches]* to cysteine *[FSP jumps onto Dorothy]* to phenyl ala–lala *[FSP circles Teresa, though Teresa cannot see her!]*



Dorothy alanine.

Teresa Yep, to that. *[Holding the beads taught]* Is this a protein necklace?

Dorothy Part of one perhaps. Course it's never simply straight in real life.

Teresa contorts her necklace.

Scene 4. *Bragg's Office at University College London 1922.*

Kathleen enters and finds Bragg standing on a chair trying to reach a book.

Kathleen Oh!– Sorry. I was told– I'm so sorry.

Kathleen hurries out of the room, waits and knocks.

Bragg Yes?

Kathleen I'm ready whenever you would like to start. I was told to hurry here. I'm just outside.

Bragg I suggest you enter and unmask yourself Miss?

Kathleen Yardley.

Bragg You can see me much better from this side of the door.

Kathleen re-enters the room to find Bragg still standing on the chair.

Yes, I thought it might be you. Take this textbook.

Kathleen Am I permitted a textbook?

Bragg I insist. Now then, what are we to do about you?

Bragg climbs down from the chair.

Kathleen Am I in some sort of trouble?

Bragg Do sit.

Kathleen removes several newspaper sheets from the chair.

Oh just pop those on the music stand for now.

Kathleen Music stand?

Bragg I play the flute. Highly recommend it - if you're up to it.

Kathleen I hope I did your *Crystals and X-rays* lecture justice in my Viva.

Bragg That is why you are here.

Kathleen Oh dear. One never knows what one's said in an oral examination. Was it a dreadful mess? It must have been. I'm sure- I expect- I hope I can do better this time. When I get too excited-

Bragg You're babbling Miss Yardley.

Kathleen Yes Sir William.

Bragg Let's get straight to the matter at hand:

Kathleen readies herself for the first question.

Define 'X-ray Crystallography' for me.

Kathleen It's a new science. A new technique.

Bragg Which is it? A technique or science?

Kathleen It's an important new science I hope.

Bragg Go on.

Kathleen You use X-rays to reveal the arrangement of atoms in interesting molecules - the way the molecule organises itself into a stackable unit – how lots of these units pack up to make a crystal. Can I start again?

Bragg Be my guest.

Kathleen You fire X-rays at a crystal and the way the X-rays bounce off the atoms in the crystal gives you vital clues about the molecule's structure. The clues are hidden in the reflected X-ray pattern.

Bragg Clues?

Kathleen To see the molecule.

Bragg Surely *seeing* requires reflected light. Light cannot discern molecules. They're too small.

Kathleen So you use the positions of the reflected X-rays to reconstruct the molecule's image.

Bragg 'You'? Who is this 'you' in your definition?

Kathleen You? You. You Sir William.

Bragg That's absurd. I can't carry out an entirely new science on my own.

Kathleen You started it, and therefore you are part of the definition.

Bragg Define *cheeky* Miss Yardley.

Kathleen It's the state I tend to take on when I'm nervous Sir Bragg- Sir William!

Bragg Are you nervous now?

Kathleen Of course.

Bragg Because of me?

Kathleen Because you are you.

Bragg How very odd.

Kathleen And because I want to answer all your questions correctly or at least intelligently.

Bragg There is one rather baffling question.

Kathleen I'm ready.

Bragg How did you manage to do so well in the BSc Physics examinations?

Kathleen I don't understand. Please could you repeat the question?

Bragg This is not an oral examination Miss Yardley.

Kathleen It isn't?

Bragg Good God no. I imagine you're glad that's over with?

Kathleen Over with? Yes! Gosh yes. Very glad!

Unless repeating the Viva would enable me to redeem myself?

Bragg Miss Yardley you stand little chance of answering my question correctly if you will not hear it correctly. *[Agitated at having to repeat]* How did you manage to do so well in your physics examinations?

Kathleen I did well?

Bragg Very well. The results are in. I don't doubt the accuracy of the marking. I happen to be the examiner. Can you explain to me why a Miss K Yardley heads the University of London list with the highest marks in ten years?

Kathleen Ten years?! I'm afraid I- I- Really? Crikey.

Bragg That's a terrible answer Miss Yardley. It's not even an answer at all. If this had been your Viva you would most certainly have failed. Recover yourself and say something.

Kathleen I honestly don't know what to say. Thank you perhaps?

Bragg It appears to be entirely your own fault – I certainly have nothing to do with it. Yet. Now, you've given us quite a new problem to tackle – namely, what to do with you? What were you thinking? – a girl taking physics!

Kathleen I like experiments.

Bragg Does teaching tempt you?

Kathleen I changed from mathematics to escape a career in teaching.

Bragg What are your prospects now?

Kathleen None.

Bragg So you have escaped *all* prospects. Have you applied for a position?

Kathleen I hope to but there seems to be a real shortage of openings. A colleague of mine

Bragg Colleague?

Kathleen with a good higher degree applied for one hundred and fifty posts before he got *one*.

Bragg You only need one Miss Yardley.

Kathleen Yes Sir William.

Bragg Where shall we find it?

Kathleen We? Did you say *we?*

Bragg Can't see a good brain like yours go to waste. I suppose I had better provide it for you.

Kathleen Cripes! Truly? That is honestly– Well it's– Crickey! Thank you Sir--

Bragg You're a diabolical babbler Miss Yardley. Who is this colleague? He's not a potential suitor I hope?

Silence.

He is a suitor!

Kathleen He's a scientist.

Bragg You're a scientist.

Kathleen Well if you think so.

Bragg Are we to lose you to a man before you've even begun? We'll make you self-sufficient. Will a grant of £180 a year suffice?

Kathleen That's more than-

Bragg I hope it saves me banning babies.

Kathleen My colleague and I have only recently met.

Bragg Early days eh? Any ideas about what you would like to work on?

Kathleen I

Bragg Not now. Go away and think about it. Read that.

Kathleen *[Reading]* Mathematical Crystallography.

Bragg Don't forget to read the inside too.

Kathleen flicks through the book in horror.

Be thorough Miss Yardley. What's wrong?

Kathleen No pictures. Oh, tell a lie. Wouldn't it be nice if you could just look up how the symmetry in crystals relates to their X-ray images rather than having to plough through all this mathematics every time?

Bragg Excellent idea!

Kathleen Is it?

Bragg Do it. Work through a definitive illustrated table of solutions to fit every potentially possible crystallography problem.

Kathleen Shouldn't it be the other way around? Surely the perfect thing would be to solve an original problem of practical significance to society.

Bragg Sadly it rarely works out like that. We academic scientists can confidently carry on being useless up to a point, knowing thank goodness that sooner or later some application will be found for our studies. The mathematician, takes pride in believing himself to be *totally* useless, but usually turns out to be the most useful of the lot. In time someone will find the real life problem to which his abstract solution is the answer.

Kathleen Am I not to conduct any experiments of my own?

Bragg Connect the theory first. Besides it will take three months or so to collect all the equipment you'll need. Everyone makes their own apparatus in my lab.

Kathleen Oh but I've never

Bragg You say this 'colleague' of yours, your suitor, is a scientist. Could he help assemble your apparatus?

Kathleen I can ask.

Bragg What better test of his devotion.

Scene 5. Kathleen's room in Bragg's laboratory at University College London 1922

1920s music as Thomas helps Kathleen build her apparatus. Their romance progresses a step with every exchange and new part. Kathleen's attention suddenly shifts to MSP (frozen, refusing to move) glimpsed through the new apparatus.

Fast forward to ***Kathleen's room in Bragg's laboratory at the Royal Institution, London 1923***

MSP moves excruciatingly slowly/undetectably. Kathleen is poised to take readings. Thomas is reduced to lesser tasks e.g. changing a plug. They have been in these respective positions for many hours. Concentrated silence.

Thomas Kathleen?

Kathleen Yes Thomas?

Thomas I-

Sage *[offstage voice – heavy Irish accent]* Feck!!

Thomas is startled, Kathleen doesn't flinch. Brief silence.

Thomas Kathleen I-

Sage Aaagh!! Almighty mother of-

Kathleen It's just Sage.

Thomas I didn't realise he was Irish.

Kathleen Only when he gives himself an electric shock.

A series of offstage thumps, crashes and glass shattering.

Sage *[from off]* Bugger!

Kathleen Or breaks something. I said he can look at my succinic acid crystals.

Thomas Do you think that's wise?

Kathleen You're not jealous Mr Lonsdale?

Thomas He's a lothario.

Kathleen You mean bohemian.

Thomas That too.

Kathleen *[still concentrated on MSP who laps up the attention]* He's stuck on graphite. Sir William wants me to teach him how to use the ionisation spectrometer.

Thomas His genius won't stand the tedium - A whole day to measure a single reflection! You'll have a broken man on your hands. Broken people break things. What will you do if he breaks your spectrometer?

Kathleen It might inspire him to invent a quicker way.

Thomas Please God if only he would! Kathleen-

Kathleen Crikey the crystals!

Kathleen returns to MSP.

Thomas Kathleen could you please look at me? I promise it won't take a second. I-

Bragg's starts playing his flute. The same 1920s tune but excruciatingly slowly.

Kathleen Remind me to pray for Sir William and his flute playing on Sunday.

Thomas Is there some place we could go where you won't be distracted by science? Or scientists! *[pre-empting Kathleen as she draws breath]* Or God!

Kathleen We could go with Sage to a Communist party meeting.

Thomas Kathleen I am leaving. London.

Kathleen That's a bit dramatic don't you think?

Thomas I have been offered a position in Leeds.

Scene 6. The Art College, Saturday morning, March 1990.

Teresa Let's have people patterns.

Dorothy People?!

Teresa Instead of a molecule, imagine a 3D model of you lot.

Dorothy Crystallographers?

Teresa Yep, kind-of-like a map, kind-of-like a family tree, kind-of-like a great big blob made from lots of twisted up protein necklaces.

Dorothy I'm imagining.. Globular is good. It might be an idea to associate the necklaces by symmetry. Each necklace may include a small number of main chains. They're different from a little bead's side chains.

Teresa Whose idea is this? *[Continuing]* What if the beads in a protein necklace

Dorothy Amino acids

Teresa yep them, the beads they could be like a whole load of oompaloompas stuck together in some special order and somehow, despite different oompaloompa's having different talents and backgrounds and obsessions, by sticking together they work as a team towards this united mission.

Dorothy Crystallography?

Teresa Yep, that.

Dorothy So what you're saying is that I'm an oompaloompa?

Teresa An oompaloompa in love.

Dorothy Oh!

Teresa Just a call. Something to do with insulin maybe? Definitely to do with your

Crystally Cristi Cristo - Christ!

Dorothy Crystallography? It might be an idea to focus on the facts.

Teresa I am. This is only the beginning.

Teresa unmasks a small model of brightly coloured beads. Dorothy examines it.

Dorothy *[Indicating the top bead]* Sir William Bragg? *[Bragg strikes a pose.]*

Teresa Correct!

Dorothy Where's Kathleen?

Teresa At the centre of the first Royal Institution

Dorothy RI

Teresa gang

Dorothy group

Teresa under Bragg in London.

Kathleen strikes a pose under Bragg.

Dorothy Only initially. Crystallographers rarely spend a lifetime in the one place. You'll find that the same 'bead' might turn up in several locations, form attachments to a variety of other beads linked in the same necklace.

Kathleen and Bragg move to a few different positions – a strange mapping dance.

Teresa You mean comparing a molecule to you lot is a legit fit?! Piece of piss this.

Dorothy You really intend to put all of us in a rigorous and accurate model do you?

Teresa Totally. Connect every oompaloompa's crystal activities right up to today.

Dorothy Golly**.**

Teresa You're shaking.

Dorothy What you're proposing is

Teresa 'too ambitious'?!

Dorothy It's terrifying. Who else do we have here?

Teresa *Sage* is it?.

Dorothy J. D. Bernal

Sage appears (his red hair on end as usual) and poses next to Kathleen.

Teresa *[Wielding a new bead]* Where do you fit in?

Dorothy To escape my suffocating supervisor at Oxford, I sought refuge somewhere around *[placing Teresa's bead]* here. In-

Teresa Cambridge.

1930s smooth music takes us to Cambridge. *As Teresa attaches the new bead Dorothy slips out of her wheelchair to eye up Sage's diffraction camera.*

Bragg I am writing about a woman graduate of Somerville College, who just got a first in Chemistry and has a great desire to work with you. She is of the rather shy type and very quiet.

Dorothy can't resist touching the camera and is caught as Sage enters the scene.

Sage Is it Miss Crowfoot? Sorry I wasn't around when you arrived. I understand you've been shown around the place?

Dorothy *[shy polite smile/nod]* –

Sage We share everything here - ideas, difficulties, sex. Would that suit you?

Dorothy Would what suit me?

Sage Us. Fervent Communists.

Dorothy –

Sage What made you want to work in my cramped little laboratory Miss Crowfoot?

Dorothy I saw your lecture on using crystallography to discover the structure of working molecules inside our own bodies. Proteins particularly. It set my mind racing.

Sage And has that produced any new thoughts or discoveries of your own?

Dorothy Only the decision that I must contribute somehow.

Sage So you have come to enlist in our cause?

Dorothy I suppose I have.

Sage My close friends call me Sage. Would you like to call me Sage?

Dorothy I- I don't-

Sage Let's get some supervision in first. This is our diffraction camera. My design. I dare say it beats Oxford's.

Dorothy You have no idea.

Sage You fire an X-ray beam at the crystal *here* and the X-rays are reflected in all directions. You surround the crystal with a piece of photographic film

Dorothy ***[taking over]*** in *here?* So when the reflected X-rays hit the film they make a revealing pattern of

Sage and Dorothy bright spots.

Dorothy Or at least one hopes so.

Sage No tutorial necessary I see. Except it also rotates the crystal through the full range of angles in the X-ray beam, giving a complete set of reflections in one run.

Dorothy Golly.

Sage We'll play with it later. For now why don't you tidy my microscope table and try to grow some decent crystals by the time I'm back from Moscow.

Dorothy Oh but – Dr Bernal! Crystals of what?

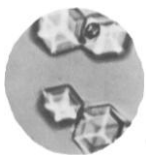
Sage *[As he exits]* You choose. Good luck.

Dorothy *[returning to her wheelchair as the storyteller]* It was like seeing gold just lying around everywhere I looked waiting to be picked up and experimented on.

Experiment.

Make it your motto day and night.

Experiment



And it will lead you to the light

The apple on the top of the tree is

never too high to achieve

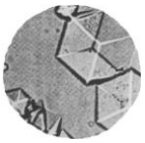
The Cole Porter song 'Experiment' plays. FSP appears. Teresa and Dorothy attempt to grow some crystals together, as big as possible.

They pour various liquids between test tubes and then mount the crystals on a slide. Every time they look down the microscope, the projected image of the crystals appears larger than before, as is FSP's dance.

Teresa still cannot see FSP and has sporadic temper tantrums. Every so

So take an example from Eve

Experiment



often Dorothy stretches her fingers/hands and is clearly experiencing pain.

Dorothy Look, now the crystals are just big enough to see with the naked eye.

Teresa Where?

Dorothy *[trying to point a specific location though her arthritic hands defy her]* There.

Teresa That really doesn't help.

Dorothy *[more unsuccessful pointing]* Just there.

Teresa What's wrong with your hand?

Dorothy *[still trying to point]* Don't look at my hand. Look there! There!

Teresa Stop it.

Dorothy accidentally smashes a beaker with her overenthusiastic pointing. Teresa clears up the breakage. Dorothy is shaken.

Dorothy Oh gosh Teresa you're bleeding.

Teresa pulls her sleeves down over her wrists.

Teresa Nope. It's alright. Just old scratches.

Sage re-enters.

Sage Of all the possible mornings not to be here you had to choose this morning.

Dorothy Why what happened?

Sage The enzyme *pepsin*. It just arrived.

Sage shows off his test tube of crystals.

Dorothy They're gorgeous.

Sage Until I took one out to photograph. It took an instant disliking to me and shrivelled before my eyes.

Dorothy These ones haven't lost any order at all.

Sage No not floating *in there*. I- I've just tried something highly irregular.

Dorothy Would you like me to pretend I'm shocked?

Sage I kept the crystal wet - photographed it in its mother liquor and look!

Showing her the photograph.

Dorothy Oh Sage!

They embrace and then quickly step away from each other.

Teresa What has he done?

Dorothy *[slipping back to her chair]* He's the very first person to ever successfully photograph a protein!

Teresa rushes to adjust her model.

Sage Your turn now.

Dorothy I couldn't.

Sage Your X-ray work is far superior to mine. I would have started you on it in the first place if you'd been here. How are the hands?

Dorothy Hands?

Sage What did the doctor say?

Teresa What did the doctor say?!

Dorothy They're fine. It's all fine.

Sage Fantastic. I promised I'd run home to Eileen but I'd like to see Margaret as well if I can squeeze her in.

Dorothy I'm sure you'll manage.

He starts to leave.

Sage I-

Teresa Careful.

Dorothy Congratulations!

Sage You too.

Dorothy I haven't done anything.

Sage Yet. Pity I can't lock you up here for another two years.

Dorothy Go and hurry off to Margaret. I'll finish your photographs.

Sage *Our* photographs for our joint paper.

Sage leaves. Dorothy starts to sneak off but quickly returns to the chair as she realises she has been thoroughly caught out by Teresa.

Teresa Why stop now? Do you think I haven't noticed you disappearing off without filling me in? Where would you have gone just then? Some magical crystal world?

Dorothy Back to Oxford first. I couldn't turn down their offer of a fellowship but equally I couldn't kow tow to my old supervisor, now head of Crystallography.

Teresa Smile, nod and carry on doing things your own way, whatever he says.

Dorothy I still needed to persuade chemistry to pay for the latest apparatus. They surpassed all my hopes and procured for me the crystals I wanted to photograph most in the world.

Teresa Insulin?!

Dorothy *[Adjusting the microscope for Teresa to see a new slide]* Perhaps.

Teresa *[Referring to Dorothy's hands]* Painful?

Dorothy I could ask the same.

Be curious

Though interfering friends may frown

Get furious

At each attempt to hold you down.

If this advice you only employ

The future can offer you infinite joy

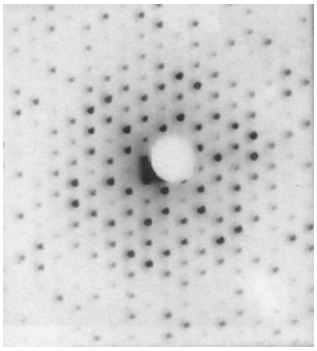
Teresa looks down the microscope. and then sets up the photographic film. Dorothy prepares the insulin crystal resuming working with FSP who is initially camera shy but is eventually persuaded to dance. Instances when X-rays reflect from FSP's dance of insulin are illuminated and

And merriment

Experiment - And you'll see.

gradually contribute to the reflected array of bright spots on the film.

Teresa and Dorothy go into the dark room and go through the process of developing the photograph – giggly/excited.



Teresa Ready?

Dorothy The moment late that evening about ten pm when I developed the photograph and saw the central patterns of minute reflections was probably most exciting in my life!

Excited, Teresa suddenly lifts the photograph out of the fixing chemicals:

Teresa *[Disappointed]* Is that it?!

Dorothy What were you expecting?

Teresa Some patterns, like the beads in some special bizarre wacky shape.

Dorothy This isn't a photograph of the molecule itself! Those are all the bright spots. They just tell you where the X-rays scattered to. Now we have to work backwards through a heck of a lot of mathematics before we even get a vague idea of where the atoms in the molecule might be.

Sage enters.

Dorothy It's insulin**.**

Sage Outstanding. Another first Dorothy. First photograph of a hormone.

Dorothy Second protein.

Sage First paper to be published under your name alone.

Dorothy Really?!

Sage You must write to *Nature* at once.

Dorothy Golly.

Sage I want to ask you about one more first.

They kiss passionately.

Teresa Hang on. Wait there. I'm not having that!

Teresa prizes Dorothy and Sage apart.

[To Sage] Please leave us.

He goes.

Is that really how it happened?

Dorothy Not exactly no.

Teresa Well?

Dorothy I was alone.

Teresa I knew it.

Dorothy But elated. I walked the deserted streets of Oxford South to the broad and there was met by a rather concerned policeman who thought I was sozzled. Or drugged.

Teresa A natural high.

Dorothy Well he sent me straight home at any rate.

Teresa And where was Sage?

Dorothy At home in bed with a fever. I wrote to his wife to pass on the good news.

Teresa He's married!

Dorothy He wanted me to try Heavy Atom Replacement to get the crucial phase data I needed to discover insulin's structure.

Teresa Whoa! Rewind – totally lost me.

Dorothy The technology just wasn't ready and neither were we. I tried to grow cadmium insulin crystals but no luck. Perhaps the material was too impure.

Teresa You and Sage carried on working together even though you were at different universities? What about his wife?

Dorothy Can we please focus on scientific facts.

Teresa He's a wanker.

Dorothy I suspect it's very tricky for you to make reliable judgements about ideals in a very different time. I wonder if it's all that helpful.

Teresa It's crucial. How can you separate the science from the people? I thought you wanted me to understand.

Dorothy Can you?!.. Golly. My entire life, the idea that something might not be possible has always been inconceivable to me but now-

Teresa I'm another first am I?

Dorothy The old methods are getting lost along with the dreams.

Sage *[Getting cosy with Dorothy luring her into Teresa's hammock]* Let's make our own Academy Dotty. The Institute for the Study of Things.

Dorothy Things?

Sage We'll break down the boundary between physics and chemistry. Attack real biological problems in society. Have all the best people, the best ideas.

Dorothy Your ideas?

Sage Join with me?

Dorothy and Sage kiss.

Teresa *[quickly interjecting]* Stop right there! Separate!

Teresa overturns the hammock forcing Dorothy and Sage to stop.

[To Dorothy] He's no good.

Sage What do we mean by 'good' and what is our criterion of goodness?

Dorothy I think I should like to live in a state run by J. D. Bernal.

Teresa Him!

Sage A good act is one which contributes to a realisation of society in which harmonious relations exist between human beings, in which 'the free development of all is the condition of the free development of each'.

Dorothy It is impossible not to get caught up by the full force of Sage's commitment to the betterment of mankind.

Teresa Don't you see how naive that sounds?

Dorothy Now, perhaps. It didn't then.

Scene 7. The Royal Institution (RI) 1936. Morning.

Two rooms connected by a corridor. Kathleen is heavily pregnant and preparing some lecture slides. If a slide is held to the light, MSP dances its contents.

Dorothy is trying to prepare her insulin crystals in her room but her arthritis is particularly bad today disrupting her experiment and FSP's dancing for her.

Kathleen Bugger.

The slide projector has jammed. Dorothy is suddenly aware of Kathleen's voice.

[Kathleen tugs at the projector] Ow! Honestly, you might have waited.

Kathleen hits the projector. Nothing happens. Two frustrated little hits. Nothing. Kathleen gives it an impressive kick. A light comes on. Success.

Why is it you manmade contraptions only respond to violence?

Dorothy Is it Dr Lonsdale?

Kathleen *[startled]* It is.

Dorothy We did meet briefly, in Cambridge. Sir William invited me here to

Kathleen You're Sage's girl! You're the insulin girl!

Dorothy Dorothy Crowfoot. Is it a bad time?

Kathleen I'm supposed to be at the Royal Society today.

Dorothy Golly.

Kathleen I turned up, looked at the programme and discovered I'm down to give a lecture. No one thought to tell me so I dashed back to pick up some slides.

Dorothy I better not keep you.

Kathleen Oh I've missed the first speaker now. How long are you in London? At the RI?

Dorothy Only briefly. Your new X-ray tube's far more powerful than ours.

Kathleen Everyone seems to be dropping in these days to take advantage of it. It's either that or the ping pong.

Dorothy I'm sorry?

Kathleen Ping pong. I'll give you a celebratory game later if you like?

Dorothy I don't play I'm afraid.

Kathleen Nonsense, I shall teach you.

Dorothy Please don't – I mean I'm sure it's awfully fun but I should make every moment here count – I mean with the X-ray tube. And you must be frightfully busy.

Kathleen Oh. I always do at least three things at the same time.

Dorothy Sage said I should try to catch you in case you can make any sense of my insulin photograph. He sends his regards.

Kathleen Yes? Wonderful man. Huge head. Outrageously active.

Dorothy He's like a magnet.

Kathleen For women?

Dorothy I meant for crystals.

Kathleen Some people say he's the reason we're getting so many young women into crystallography.

Dorothy Maybe you're the reason.

Kathleen I think it's Sir William. The father of crystallography trusts us with his baby.

Dorothy Yes, even after you left his baby to have your own baby.

Beat.

Kathleen I didn't leave.

Dorothy I didn't mean

Kathleen I paused.

Dorothy And soon you will pause for the second time.

Kathleen Third time.

Dorothy Three pauses!

Kathleen Three babies.

Dorothy How wonderful.

Pause.

How long is a pause?

Inner cringe.

Kathleen I usually take my calculations into hospital. Last time I managed to get a good deal of work done in between the first lot of contractions.

Dorothy You do take time off after the birth don't you? To-

Kathleen It is the most precious time you could ever wish for – being with your babies. It gives you the opportunity to stand back and look at your work with new eyes which brings new ideas. Highly recommend it - if you're up to it.

Tumbleweed.

Dorothy I should check on my insulin crystals.

Dorothy goes back next door mortified at her faux pas.

Teresa Go back and ask her to help you with insulin.

Dorothy I did. She's busy. Pregnancy is a firing offence for most women.

Teresa Not her clearly. How come?

Dorothy Kathleen's the exception.

Digression to the Lonsdale's home in Leeds 1929

Kathleen I hate succinic acid.

Thomas Well that's just ridiculous.

Kathleen I know. Everyone will know I've made an error.

Thomas How will they know?!

Kathleen I published it.

Thomas Ah.

Kathleen And now I'll have to publish a retraction. Sir William's probably done it for me. It's probably in that parcel.

Thomas It's probably a present. Did you tell Sir William about our news?

Kathleen He said 'intelligent women should have children'. Even in Leeds. Of course most women-

Thomas Most *people* don't manage to fall upon a new job offer when they're not even looking.

Kathleen I suspect Sir William had a hand in it which makes both working and not working awkward.

Thomas Decisions will only get more difficult when there are three of us. I'd better make all of them from now on. Including whether you continue to work!

Kathleen *[in shock]* I see.

Thomas First thing on Monday you will go to the university, and tell them- Wait a minute, what's awkward about working if Sir William recommended you?

Kathleen They want me to find the structure of Benzene.

Thomas I thought Sir William had already solved Benzene.

Kathleen Yes exactly. Unless it's flat not puckered.

Thomas You mean even the great William Bragg could have made a mistake?

Kathleen It isn't a mistake like my mistake. He might still be right.

Thomas And I suppose you'd like to settle the matter? Well I won't have it. Northern women know how to behave. You'll soon learn.

Kathleen I was going to insist that I give up work and stay at home like a good wife and mother but if you're going to

Thomas But nothing! – You will go to the Leeds Physics department and accept the new position.

Kathleen Hang on – didn't you just say

Thomas Take the job. I didn't marry you to get a free housekeeper!

Kathleen You absolute rotter!

Thomas You must've known I was pulling your leg.

Kathleen I don't think I can do it Thomas.

Thomas You will do it because it is what you do.

Kathleen Not after my horrific mistake. And I couldn't cross Sir William. What about when the baby arrives? I'm scared.

Thomas Come here woman. It's just a little confidence knock. Stuff the job if you like - but keep on with your calculations while I build you new apparatus here at home. We'll have to be very careful with money that's all. We'll go shopping together. We'll make bread!. I still think you should take the job though.

Thomas suddenly goes for the parcel.

Kathleen Don't! *[Launching at Thomas to restrain him]* Thomas don't! Please don't.

Thomas Either we open it now or we throw it out. Do you want me to throw it out?

Thomas takes out a small microscope.

The first addition to the Lonsdale laboratory!

He takes out a letter.

Kathleen I'm not listening.

Thomas Pity. It's from the Royal Society.

Kathleen What?!

Thomas They've had to reprint your Crystallography Tables.

Kathleen Why? Is there a mistake in that too?

Thomas This copy is for you.

He flicks through it.

Kathleen it's

Kathleen all wrong?!

Thomas No it's beautiful. You drew all this?

Kathleen It's just a handbook.

Thomas Practical and pretty. Isn't beauty a sign of truth?

Kathleen I thought it was all there. All done. Anyone could just look up the missing bright spots on a molecule's photograph to narrow down a crystal's space group.

Thomas *[Scanning the letter]* They want you to work on a more exhaustive edition.

Kathleen Why did they reprint it if they want me to redo it?

Thomas *[Scanning/teasing]* Ah.. Aha!

Kathleen What is it?

Thomas Oh dear.

Kathleen Thomas?

Thomas Crikey!

Kathleen It's not funny!

Thomas It seems the last lot of books they printed sold out. There's been far more demand than supply.

Kathleen You're very cruel to joke about that.

Thomas I'm not. They want you to collaborate on an International edition. It's bloody brilliant Kathleen! *You're* bloody brilliant!

Kathleen Gosh I- Really?

Thomas There's a note from Sir William here too. Ever the bearer of good news. *[reading]* **'**I am' - Oh

Bragg I am concerned that after the arrival of your baby it will be far too difficult to do everything in the home and also find time for research.

Kathleen I shouldn't have told him about the baby!

Bragg I have been in touch with your new department at Leeds

Kathleen Everyone knows!

Thomas and Bragg together Our managers here at the RI have secured you a grant

Bragg for a daily domestic helper, a one Mrs Snowball, to assist you with washing, cleaning and additional childcare so that you can further your structural analysis.

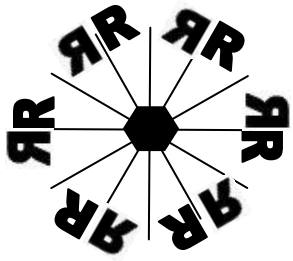
Thomas Genius! What do you think?

Kathleen I think- I think- Goodness-

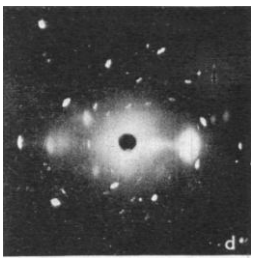
Bragg You're babbling Kathleen.

Kathleen I think we should meet Mrs Snowball.

Thomas lifts a statue-like MSP out of the parcel. Kathleen detects MSP's awkward movements which become more fluid and clearly relate to his earlier 'R' motif but with

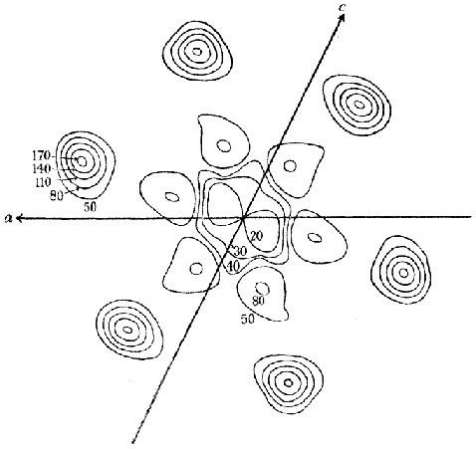


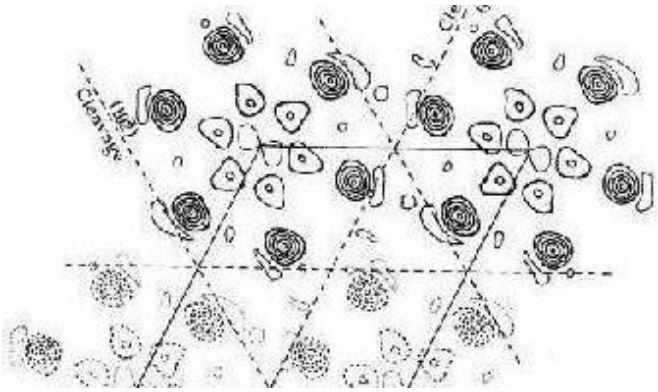
six-fold symmetry, as shown left. A projected X-ray photograph gets clearer:



Kathleen tries to understand the science first by notes/calculations in her lab book and then by copying MSP's movement herself, eventually achieving unison with MSP and a rapport - success!

MSP partners Kathleen, by dancing in the high contour areas of these maps of H_6Cl_6 hydrochlorobenzene as she draws them.





Dorothy To ‘see’ a molecule you can mathematically reconstruct its image by making a contour map as a guide with steep mountains where the atoms are. The mathematical results you plot rely on two types of data from your photograph; the bright spot intensity and the-

Teresa phase?

Dorothy Quite. For the intensity, you assign each bright spot a number on your own made up scale from extremely intense to totally missing

Teresa but the phase?

Dorothy Needs a bit more cunning. Imagine a wave travelling towards the crystal.

Teresa Like a water wave moving towards a wall.

Dorothy Brilliant. On the approach all the waves are in phase, they’re at the same stage within a wave cycle, going up together

Teresa down together.

Dorothy Yes, at the same speed. But when a wave reflects off the wall (which is like bouncing off an atom in the crystal) the phase changes, because the atom’s electrons create a field which slows the wave down.

Teresa No don’t get it.

Dorothy It is as if the water has transformed into thick treacle.

Teresa which makes the wave get behind in its up down cycle?

Dorothy Exactly. The waves scattering off vast numbers of atoms all over the crystal become out of phase with each other, depending on where the atoms are and what

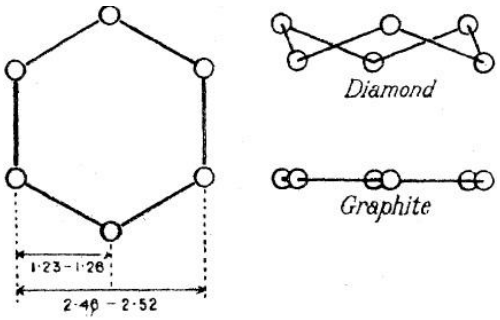
they are. The more electrons a type of atom has, the thicker the treacle around it.

Teresa - the more behind the wave gets.

Dorothy Of course finding measurable evidence for the phase is a complete nightmare. A cheat for small molecules like Benzene is to guess the molecule's shape first, then do the corresponding mathematics and see if it matches your data.

Teresa Whoa! Guess the shape how?

Dorothy Benzene only has six carbon atoms in a ring. It could only be flat like graphite or puckered like Diamond. Kathleen proved it was flat.



Teresa Great! So just guess the shape of insulin!

Dorothy Insulin has four hundred and six atoms. That's not including the hundreds of hydrogen atoms.

BACK TO 1936 AT THE ROYAL INSTITUTION. *Kathleen pokes her head into Dorothy's room. She has her Crystallography Tables with her.*

Kathleen Would you like me to look at your insulin photograph?

Dorothy Oh I would. I would appreciate that very much. Very much! Sage would too.

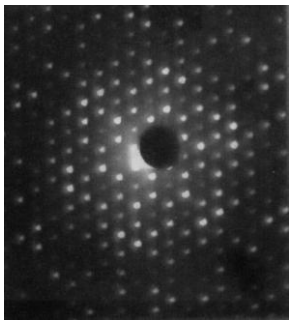
Kathleen You be careful there. You solve insulin. Don't listen to all the negative remarks.

Dorothy What negative remarks?

Kathleen About protein research. Impossible? Wonderful! You solve insulin.

Dorothy I very much hope to.

Kathleen Good. Now let's see this photo.



Kathleen holds Dorothy's insulin photograph up to the light.

FSP dances. MSP pokes his head around the door to watch.

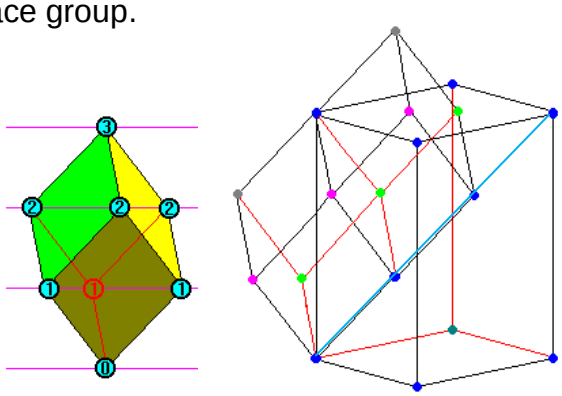
Very promising. Wonderful detail. And as to what it all means

Dorothy Yes?

Kathleen Haven't got a clue. Don't fret.

Kathleen opens her Crystallography Tables as if they'll save the day.

Dorothy Oh I've already looked up the space group.



Dorothy looks despondent.

Kathleen Is it really as bad as that?

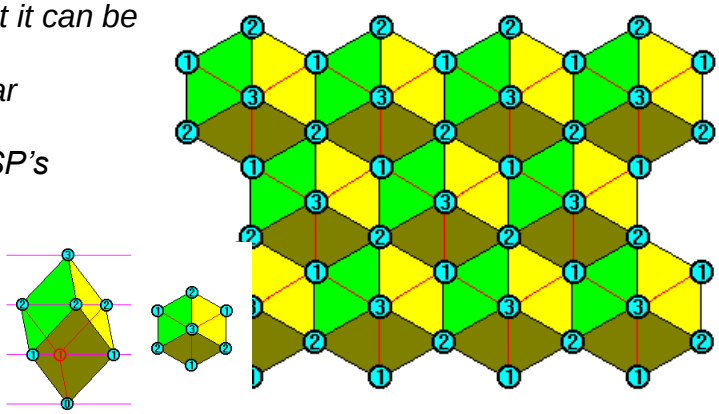
Dorothy Trigonal rhombohedral.

Kathleen Ah... I am so very sorry Dorothy.

FSP tries repeating her insulin dance inside the stacked rhombohedral unit cells:

Perhaps thinking of it hexagonally might give away the three-fold symmetry.

The rhombohedron rotates so that it can be viewed from the top and so appear hexagonal. This hexagon (and FSP's dance within it) multiplies up and tesselates, as in a crystal,



reflecting Kathleen and Dorothy's shared thinking:

Dorothy Golly!.. Any other advice?

Kathleen Keep at it. No one has ever captured such a large molecule before. Start the work and pray that technology catches up with you. It may take some time.

Dorothy It's very difficult to accept that when so many people are still dying from diabetes.

Kathleen Well I- I- I'm afraid I better run. Ping pong later?

Dorothy I tend to keep rather unsocial hours in the lab.

Kathleen You mustn't work too late if you're walking back through London alone. Where are you staying?

Dorothy Bloomsbury. With my old principal from Somerville.

Kathleen There's no one young who could escort you back - show you around?

Dorothy Her nephew is staying there too but I don't have much time for sightseeing.

Kathleen Nonsense. If you want to succeed as the first class scientist you should be, the first thing you must do is choose the right husband. What's this nephew like?

Dorothy I really couldn't say.

Kathleen Don't be shy Dorothy.

Dorothy Tall with fair hair.

Kathleen Yes?

Dorothy A passionate communist, like Sage.

Kathleen Aren't we all.

Dorothy He just resigned from his job in Palestine. They've thrown him out of the country!

Kathleen Outrageous. What's his name?

Dorothy Thomas Hodgkin.

Kathleen Perfect. He's perfect!

Dorothy Do you know him?

Kathleen No, but I like his name.

Dorothy Hodgkin?

Kathleen Thomas. How exciting. Love is a very strange microscope! It doesn't do to get stuck on the wrong sample, if you catch my drift.

Dorothy I'm not sure I do.

Kathleen If after some time your sample refuses to yield itself fully, you might want to find another one. Crikey!

Kathleen picks up the slide projector.

Lecture over - on to the next! Very nice to see you again. Ah nearly forgot my Crystallography Tables.

Dorothy Oh, that's my copy - of your tables.

Kathleen Is it?

Dorothy It's my bible. I think this is yours.

They swap books.

Kathleen Thank you.

Dorothy Are you alright to carry all that?

Kathleen Eh?

Kathleen drops her slides as she turns.

Bugger.

They both instinctively bend down to pick them up.

Dorothy I'll do it.

Kathleen It's fine really.

They both struggle to clear up the slides. Dorothy's inability to grip the slides effectively is painfully obvious.

This will keep me on my toes, not knowing which slide is coming up next.

Awkward pause.

Is there anything I can do Dorothy?

Dorothy It's just a bad day.

Kathleen Have you seen a doctor?

Dorothy Oh yes.

Kathleen Really?

Dorothy A specialist. The morning Sage photographed pepsin.

Kathleen Can you work like that?

Dorothy I'm sure it will pass.

Kathleen Did the specialist say it will pass?

Dorothy If I rest. Thank you for looking at my photograph, I'd hate to make you late for your

Kathleen Arthritis?

Dorothy nods.

What does rest mean?

Dorothy Stopping all experimental work until my hands are improved.

Kathleen Then you shouldn't be here. Have you stopped at all?

Dorothy I might get more interpretable photographs of insulin.

Kathleen Don't be so heroic Dorothy. Insulin's difficult enough without you trying to hide your inability.

Dorothy I've managed all the possible measurements.

Kathleen What about the phase problem? You can't expect to solve unknown structures as large as proteins, unless you push crystallography itself. I'm sorry Dorothy it won't do. Get your coat.

Dorothy I'll speak to Sir William first.

Kathleen *[Handing Dorothy her coat]* I strongly suggest you come with me to the Royal Society instead.

Dorothy The Royal Society?!

Kathleen Possible solutions to impossible problems – discuss! It's the only way - however hard.

[Taking her own advice/gathering courage to confess at last] I rather suspect my father was a diabetic but didn't know it.

Dorothy It's a common mistake- I mean oversight- I mean-

Kathleen There were clues. He was irritable, alcoholic, always ill and therefore unemployable - I'm not just making an excuse for him. He died very early really.

Dorothy I'm sorry.

Kathleen No need. As the youngest of ten siblings' I received plenty of hand me down knowledge. Their joint earnings even afforded me the luxury of school. I dare say crystallographers now act as a similar family of sorts.

Dorothy Yes.

Kathleen A chap called Patterson thinks he can get around the phase problem by taking mathematical maps to the next level. Would you like me to make the introduction if I can?

Dorothy Golly! I- Oops *[Dorothy attempts to do up her coat but is all fingers and thumbs]*.

Kathleen Don't dawdle Dorothy or I shall introduce you as the girl who made me late for my lecture.

MSP and FSP re-meet and spark off each other – they start to join forces.

Scene 8. The Art College. Saturday evening**.** Dorothy is lying in the hammock snoozing while Teresa works. She is smoking a cigarette which clearly relaxes her.

Teresa It's past six Dotty. Your daughter will be waiting. Fuck off downstairs will you.

Teresa checks Dorothy is still breathing. She covers Dorothy with her coat to keep her warm.

Would you'd rather stay here with me tonight?.. Bragg saw something in Kathleen and Sage, they saw it in you and now you in me. – If you do you're the first. Another first!. What do you see in me?

My tutor thought I must be seriously lazy for sleeping as my project presentation. Then people started doing stuff they'd never normally. Some nice. The worst was this girl and guy having a conversation over me when the sleeping pills were wearing off. A friend in their year had died, I'm guessing from AIDs, and they'd misheard about why I claimed to have HIV. They thought it was part of my project - why I was lying there. They wished it was me dead instead. The guy had a craft knife on him and he was saying that he'd really love to stick it in me but he couldn't do it. He couldn't cross that boundary. So I went and got a knife too and started to prick myself a bit – still sitting on the hammock. On display. And people started to stop and watch. And I stopped and tried to work out what they wanted. What they needed. And then I cut a bit more, and more people stopped and watched. And I'd lift the knife and I had their complete attention. And I'd rest it on my skin. And wait. And check in with them. And then pull the knife across. A bit. More. People. Slide. Blood. Then I'd rest. A bit. But they were waiting. So I'd start again. I would explore different areas of my body and then try to check in with them to see if I was getting hot. And it went on. More people came. Some people walked away. But nobody stopped me. I think I must have hit a

big vein. The doctors fucked up the poetry for everyone. I'm still here. The doctors really fucked that up. Now everyone just remembers it as this weird stunt but it could've- *[Teresa stops mid-thought to pick up the cuddly teddy.]*

I think Julia, the numskull, must have visited me in hospital because I woke up with her favourite bear on my pillow - you say 'her teddy'.

Teresa put the teddy on Dorothy's pillow.

Life ends but art and science last I reckon. They can. I guess maybe you're more likely to discover something if you keep living and keep trying.

Dorothy *[dreaming]* I had to write this to put myself at rest for the day.

Teresa Write what Dotty?

Dorothy I'm not nearly so unmoved by these things as I might seem. It is not possible to finish the insulin paper under so great stress.

Teresa You're having a bad dream.

Dorothy I'm feeling still very exalted though.

Teresa A good dream.

MSP gently lifts, rocks and swings Dorothy as Thomas Hodgkin would, supporting her through the emotional journey of her dream. Dorothy floats in euphoria.

Dear Thomas don't mind too much and have a little patience.

Teresa It isn't Thomas it's Teresa Dotty. Teri?

FSP lures Teresa with the crystal book. Teresa can't see FSP but starts to sense her.

I swear I'll grow you a new crystal Dotty. You'll have commissioned a scientist!

Teresa tries to grow a crystal just as Dorothy taught her earlier.

Sage enters. Dorothy opens her eyes but continues to dance/be supported by MSP.

Dorothy *[to Sage]* It doesn't seem to be the same sort of being in love. I feel so perfectly happy and oddly virtuous.

Sage Will you want to start a family?

Dorothy Of course.

Sage Give up your work?

Dorothy Do you think it will come to that?

Sage Perhaps not. Sitting around X-ray tubes all day has been known to cause infertility Dotty. And potentially deformity. In the child.

Dorothy looks down to find she is pregnant. FSP dances insulin frantically.

Dorothy I've been so incredibly stupid. Up til now I've allowed all the insulin crystals to dry. That's why the data is so poor. I'm starting again. The new crystals are so very beautiful! Imagine the sheer number of bright spots if I photograph them wet like you did with pepsin - keep the best order.

Sage They look fragile. Capture them quickly.

Dorothy The minute I get back to Oxford.

Sage If war breaks out will you look after my equipment? And two of my researchers – refugees. For your own work. Keep crystallography going.

Dorothy I promise.

Sage You'll have to source any new crystals yourself. Don't miss this set. Be quick.

Dorothy Yes.

Dorothy's water breaks. MSP returns as a doctor and leads Dorothy away from FSP.

Sage For once I'll finish *your* photographs for *you*.

Sage exits taking FSP.

A baby cry is heard. Dorothy reaches for it but MSP passes the newborn to FSP (who returns in the guise of a nurse). MSP restrains Dorothy's hands. FSP brings the child to Dorothy to breastfeed, reweighing it after each attempt.

Dorothy Sage dear? It's beastly. I've had a breast abscess and the doctor won't let me travel to you. The child's perfectly healthy if only he could feed. Another thing - I don't recognise my hands anymore. They look terrifically crippled and they won't- I'm not able to- It's difficult- I want so very much to hold my baby. I can't help my own baby to feed.

Tell me sometime about insulin.

A siren signals the start of World War 2.

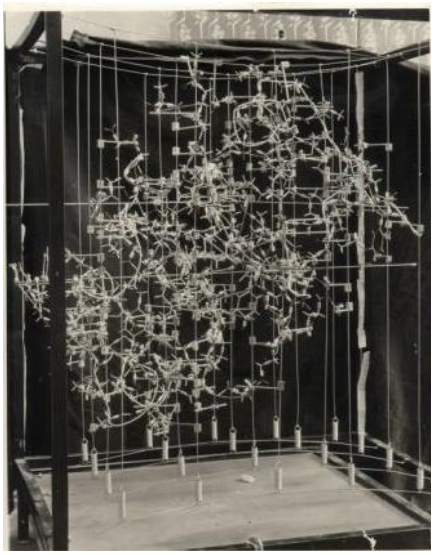
We shift focus to Teresa who stares at a test tube held up to the light believing she has failed to grow a crystal by herself.

Teresa Bugger

Frustrated she dares to turn to the page in Dotty's book showing the diabetic boy: 'Pre-insulin. 3 years old. 15lbs'

End of Act 1.

Act 2.



Scene 1 Sunday Morning 1st April 1990. Art College.

Dorothy wakes to find Teresa's clothes strewn about but no sign of Teresa. She unveils an extremely full model of folded fixed necklaces of beads forming a globular shape overall – not dissimilar to Dorothy's model of insulin:

Thomas Lonsdale enters wearing an apron, transporting us to Dorothy's house in Oxford – A post war memory.

Thomas Would you like to be mother?

Thomas hands Dorothy a carving knife. Kathleen and Sage burst out of the model.

Kathleen Post.

Kathleen hands Dorothy a letter

Sage Smells phenomenal.

Thomas Cutlery Dorothy?

Dorothy By the sink.

Kathleen Is it alright if the children eat their lunch in the tree house?

Sage Your daughter's a rotten footballer Dotty.

Kathleen We beat the boys.

Sage *[To Kathleen]* Discussing the ethical agenda for the first *International Union of Crystallography Conference* while scoring a goal is an outrageous tactical distraction.

Kathleen Can't you do two things at the same time? Look at Dorothy.

Dorothy is attempting to engage in the conversation, open/read the letter and carve the joint simultaneously. Whenever Dorothy looks at the letter, MSP and FSP appear at the next point in their respective straight line sequences (see insulin's A + B chain below). Meanwhile Thomas adds the final touches to a magnificent nut loaf.

Thomas I've made a vegetarian stuffing for Kathleen and me. Anyone else want any? Sage?!

Thomas hands the knives and forks to Sage and Kathleen who start laying the table.

Kathleen You'll come to the first IUCr conference wont you Dorothy?

Dorothy I don't think I'm invited.

Sage Of course you are. You promised you'd join *Science for Peace* too.

Dorothy I'm not sure it's really my field.

Sage *[To Dorothy]* Love letter from Thomas?

Kathleen Peace isn't your field?!

Thomas War on war!

Kathleen It's such an outdated means of settling disputes. Unlike your more discrete methods.

Dorothy I'm sure I don't know what you mean.

Kathleen Sticking up for the young women at Somerville College?!

Thomas Perhaps what this country needs is a scientist Prime Minister.

Sage How about a woman Prime Minister?

Dorothy Don't look at me.

Sage Kathleen would you consider the position?

Kathleen Scientists are no better equipped to rule than anyone else. Although politicians would do well to attempt to quantify their uncertainties as diligently as scientists do. I'm sure Dorothy's Thomas has a far better understanding of different world attitudes than any of us.

Thomas Looks like gripping news.

Dorothy Oh no. Or rather yes. But the letter isn't Thomas'. Fred Sanger wants to know if my maps match his insulin sequence.

Kathleen And do they?

Sage Look at her, she's bursting to fetch her maps.

Thomas Put the knife down Dorothy.

Dorothy I'm sure I can hold out til after lunch.

Sage Well I can't! Where are they?

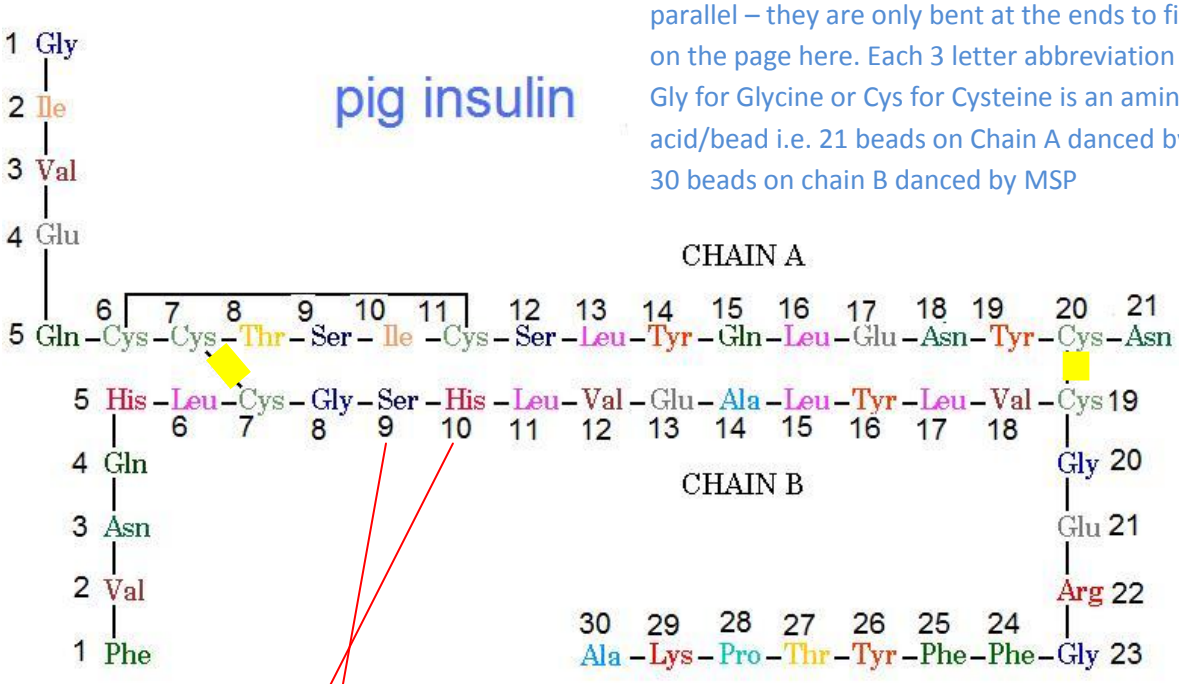
Kathleen *[Excited]* Crikey!

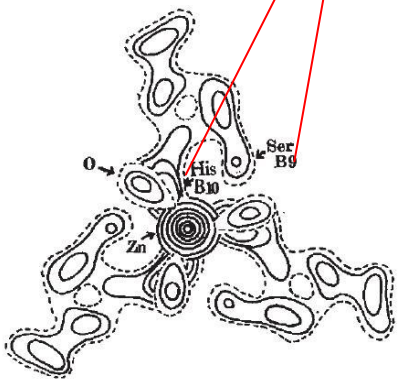
The tune played earlier on Braggs flute is jazzed up and speeded up. Kathleen, Sage and Dorothy spread the transparent maps sections over the big kitchen table and try

to match them to MSP and FSP's dance of two parallel straight line chains. If successful, their turning map is projected (please see below).

Kathleen Two main chains in the molecule?

Dorothy Yes one slightly longer than the other.





Sage Better watch out if those two cysteines get together.

FSP and MSP launch at each other and link at bead 7.

Kathleen Too late.

Thomas Nut loaf? *[Thomas feeds Kathleen.]*

Kathleen So reactive!

Sage They just bridged the two chains!

Dorothy And again.

FSP's Cysteine (Cys) bead 20 on chain A and MSP's bead 19 on chain B connect.

Kathleen Two bridges to hold the structure together. How exciting Dorothy!

Thomas pours a glass of wine for Dorothy and Sage, and tea for him and Kathleen.

Thomas To insulin moving again!

Sage and Kathleen To insulin.

Dorothy I'm supposed to be working on Vitamin B12. Every new molecule takes me further away from insulin.

Kathleen It's through tackling other structures that you've pushed crystallography on.

Thomas orchestrates the clearing and relaying of the table.

Dorothy I don't know how you two manage all your political exploits on top of research.

Sage My group get on with the frontline nitty gritty. It's their triumphs now.

Kathleen Your ideas.

Dorothy Don't you ever need to follow an idea through to its conclusion?

Kathleen Yes, when did you last solve a complete structure? Graphite?

Sage Depends what you mean by complete.

Kathleen Crikey.

Dorothy Locate every atom in its exact three dimensional relationship with every other atom.

Sage Every atom! Get yourself a computer Dotty. Better hire in several computers.

Kathleen You mean women I suppose?

Sage who do mathematical data processing. Highly recommend them.

Thomas Why women?

Sage The work requires delicacy of hand and eye and patient industry in drudgery.

Kathleen They're fast and cheap.

Dorothy Two brilliant young men are helping us with B12 using the latest mechanical computer in California.

Thomas and Sage with Kathleen *[pre-empting her]* Crikey!

Dorothy Patterson calculations that would have taken us months, can be done in a single night. They work right through the night.

Thomas I bet their wives aren't too happy with you.

Dorothy If we ever hope to see solutions to protein structures in any of our lifetimes I'm afraid your *[Sage's]* computing women will need to be replaced by machines.

Thomas One day there will be a computer program to replace crystallographers.

Kathleen Crystallography isn't just good needlework.

Thomas And computing is?

Kathleen There's no replacement for good crystallographic nous. No person, let alone a machine, could know every detail of Dorothy's insulin maps as intimately as she does.

Dorothy Still no solution yet I'm afraid.

Kathleen There will be.

Dorothy If we push computing. As it is, my group's record breaking demand for computing services has been brought to the attention of the powers that be at Oxford.

Kathleen Are you in trouble Dorothy?

Sage How can she be after solving penicillin?! You should get the Nobel Prize.

Dorothy I would rather be elected a Fellow of the Royal Society.

Sage That's more difficult. The shockwaves still haven't settled since– since-

Kathleen I did say I wouldn't accept the FRS if it caused dissension amongst the ranks.

Sage There's always a push post war to re-establish men as men and women as-. Oh it's all nonsense. As is restricting your spending on computing.

Thomas Enjoy the resistance before things really start getting out of hand.

Dorothy What do you mean?

Thomas Do you want mechanical computers plotting all your maps for you?

Dorothy If only.

Thomas Robots growing crystals for you? Interpreting your data, spotting all your mistakes?

Kathleen How could they possibly?

Thomas It's starting already.

Sage Skill and heart must be sacrificed for the greater good.

Thomas At what cost? Who's good is greatest?

Thomas exits.

Sage So suddenly scientific progress is a bad thing across the board is it? No one here is building the next nuclear bomb are they?

Kathleen He has heard worrying reports about scientist friends of ours missing in Soviet Russia. Because of friends of yours. Your comrades.

Sage So investigate. Go there and see things for yourself.

Kathleen Crikey!

Sage I'd be happy to arrange your travel. Be your guide. Bring your Quaker group along with you if you like.

Kathleen The idea is positively thrilling but-

Dorothy Perhaps Sage might also be able to make enquiries and introductions for you - to help discover the whereabouts of your friends.

Sage I'll do what I can. Should I go and have a word with Thomas?

Kathleen He'll be back once his fruit pie starts burning.

Dorothy I didn't realise we had any fruit.

Kathleen An apple fell on his head sitting under your tree house. Goodness the children must be starving.

Kathleen exits taking a tray of food.

Sage Dotty, while I've got you to myself-

Dorothy I think I should kidnap Thomas Lonsdale.

Sage Not for my sake?

Dorothy My Thomas always says 'What my wife really needs is another wife'.

Sage Mr Lonsdale is quite the domestic God... Dotty I really think I could do it!

Dorothy You'd be a terrible wife.

Sage - raise the capital for our dream institution.

Dorothy Golly.

Sage Are you in? Everything would be possible if the whole Cambridge gang could work together again – world peace – proteins.

Dorothy Oh Sage - aren't you happy at Birkbeck? You seem it.

Sage They tolerate me pretty well considering.

Dorothy It couldn't be your dream institution?

Sage Will you join me there?

Dorothy We're all nicely settled in Oxford now.

Sage Your very own group?

Dorothy And my family. We have a floating institute don't we? Always dropping in on each other.

Sage I hope we might all be together for the first International Union of Crystallography Conference. *[On one knee]* Do you promise to come?

Dorothy I do.

The lift is heard and the 'up' light flashes as we return to the art college.

As Sage exits Dorothy desperately tries to put the hammock back and climb into it at the last second.

Teresa enters wearing a 1950s style light shirt and skirt.

Dorothy Goodness, is it?

Teresa It's Teresa Dotty. Jesus, you're not still in some dreamland!

[Posing in her outfit] Like it? I was trying to imagine- Are you feeling alright?

Teresa helps Dorothy into her wheelchair.

Dorothy A bit stiff.

Teresa It's a lovely day.

Dorothy Day! It's impossible to tell what time it is in here. My daughter will be worried sick.

Teresa Do you think art is important?

Dorothy Do you need an advance on the portrait fee?

Teresa I walked down to the National Portrait Gallery like this - for inspiration.

Dorothy You look very smart. Very elegant. So very much like

Teresa I'm not like anyone. I wish I was. Like who Dotty?

Dorothy Someone misremembered.

Teresa The gallery's advertising this competition. Can you stick around so I can finish this in two weeks?

Dorothy Two weeks!

Teresa For the competition. Your daughter won't mind you staying with her will she?

Dorothy Golly I should ring her.

Teresa Yeah you should.

Dorothy You don't mind?

Teresa What?

Dorothy How?.. How do I make a call?

Teresa There are payphones by the entrance.

Dorothy Yes.

Teresa *[realising Dorothy is suspicious of her]* Jesus.

Dorothy Well that's excellent. I'll just go and-

Teresa Did you think I'd stop you?

Dorothy Why didn't you wake me?

Teresa I tried. I didn't want to interrupt - You looked so- 'exalted'! But then suddenly it was way too late and there was no point.

Dorothy All of a sudden too late to leave?!

Teresa They lock the building.

Dorothy My poor daughter.

Teresa Phone her. Ask if you can stay in London a bit longer.

Dorothy I'm supposed to go to America next week.

Teresa What? Don't. You can't.

Dorothy Of course I can.

Teresa So you're abandoning me?

Dorothy That's rather melodramatic don't you think?

Teresa Why didn't you tell me?

Dorothy I wasn't certain you'd actually committed to the portrait.

Teresa I worked all through the night.

Dorothy Yes I saw. It looked very

Teresa unfinished? Soulless?

Dorothy The backbone to your necklace is definitely - taking shape. Though you seem to be using the same beads over and over again.

Teresa You said I should!

Dorothy - in the early days. After the war the sheer number of crystallographers shot through the roof.

Teresa Why?

Dorothy A mass exodus from the science of death and destruction to the science of life.

Teresa Proteins?

Dorothy The search for the molecule which carried genetic information to the next generation. It turned out to be much much simpler than a protein. Very elegant indeed.

Teresa Help me simplify this mess here. So people get it. What's the overall pattern?

Dorothy Finish it first. Be thorough.

Teresa How big is it going to get?

Dorothy The IUCr's directory lists at least two thousand people at the moment– across fifty-two official countries.

Teresa Whoa! So my model is harder than insulin?! Only four hundred and six atoms in insulin you said.

Dorothy Not including the hydrogens. Fifty-one beads across two chains. Haemoglobin's a better comparison to your task.

Teresa Haemoglobin?

Dorothy The molecular lung. It has several thousand atoms. Max Perutz devoted his life to solving its structure.

Teresa Max who?

Dorothy I should go.

Teresa No. Wait. Max!

Teresa checks through a list to go with her model.

Dorothy Max never got distracted by other molecules like I did.

Teresa I put Max Perutz here, is that right? *[Max Perutz, Sage and Bragg take up their appropriate places as described]* He starts out in Sage's Cambridge gang.

Dorothy Yes then when Sage left Cambridge, Max stayed on as second in command to Sir Lawrence Bragg,

Teresa Bragg!

Dorothy Sir William's son. Sage was thrilled Max and I could both continue the quest to solve the first protein structure.

Teresa Sage set you up in competition with Max Perutz?

Dorothy Not at all! Max and I shared all our ideas.

Teresa Like what?

Dorothy The phase problem.

Max -still our Achilles heel!

Dorothy Even twenty years on.

Teresa What about that dude – Patterson! Didn't his maths help you find the phase?

Dorothy Only if you know the position of at least one atom

Max in the unit that repeats over and over again to make the crystal.

Dorothy You need one atom's position as a reference

Max to find all the other atoms.

Dorothy Heavy atoms usually make the best position reference. If they don't exist naturally in the molecule you try to attach one inside it somehow.

Max Once in they're much easier to locate than light atoms

Dorothy because they have a much bigger scattering effect on the X-ray waves,

Teresa which makes a bigger difference to the bright spots on the photograph?

Dorothy *So* big it's actually measurable!

Max Well people certainly found that to be true for small molecules.

Dorothy Good Teri.

Max Everyone thought it would be impossible to detect one or two heavy atoms in a protein.

Teresa *[Carried away with excitement/new confidence/putting Max down.]* Well yeah! Proteins must be massive compared to a single atom! Even a really heavy atom.

Dorothy *[Cutting Teresa back down to size and inflating Max]* Max refused to accept that sort of popular pessimism. He blew the phase gloom to bits. He proved that the difference from adding one or two heavy atoms to a protein *could* reveal the phase because most of the light atom reflections cancel each other out!

Slow clapping from Teresa. Max acknowledges Dorothy gratefully and manages a modest exit.

Teresa Didn't Sage already tell you all this heavy atom stuff when you took the first ever insulin photograph? Why weren't you on to it?

Dorothy It wasn't for lack of trying. The arrangement of atoms in insulin is so compact it's virtually impossible to get any heavy atom into it without altering the entire molecule.

Teresa Did Max manage it with haemoglobin?

Dorothy Of course, it's enormous! A maharaja's elephant takes no more notice of a gold star on its forehead than haemoglobin does of a heavy atom or two.

Teresa So Max beat you then. He won.

Dorothy 'Won'? - What?

Teresa The race to solve the first ever protein structure?

Dorothy Not quite – there are thousands of atoms in haemoglobin remember. In practice that means around a million bright spot reflections to measure and process.

Teresa Ok so both haemoglobin and insulin are impossible.

Dorothy No. We never believed that for a second.

Teresa Is my structure impossible?

Dorothy Max and I always knew our solutions were just around the corner. They had to be.

Teresa - for the good of society! My model isn't gonna save anyone's life is it? What's the point?

Dorothy What do you think? As an artist?

Teresa Winning a competition.

Dorothy Oh Teresa.

Teresa Help me get inside that thing there before it turns into a monster.

Dorothy Does that have to happen - in art?

Teresa You want me to cheat - change something?

Dorothy Stay faithful to the rules, to the process. Be thorough.

Teresa Then help me see what you see, in the gaps.

Dorothy Just like that?

Teresa You don't think I can.

Dorothy Perhaps after years and years of patient repetitive exploration, piecing together all the data and knowledge you can gather, knowing the nuances of each map contour so well that the smallest new detail instantly reveals a whole host of hidden precious patterns. Years! Not two weeks.

Teresa I can't spend years on one project. I can't even imagine years. I'd be a totally different person by the time I finished.. *[Getting it]* You chose me because I'm young.

Dorothy It helps.

Teresa You'd give America a miss to help me wouldn't you?

Dorothy I thought you were helping me.

Teresa But now there's a competition.

Dorothy Are you likely to win?

Teresa I know I will if you stay and- I need a new start. Are you going or not?

Dorothy I can't get an American Visa at the moment - because of my affiliation with certain organisations.

Teresa No shit! You're blacklisted?!! Awesome. Which organisations?

Dorothy Science for Peace. Either that or the Girl Guides. If my daughter can't sort it out no one can. She's probably searching for me as we speak.

Teresa Best stay here then. It's where she last left you. It's fate.

Dorothy makes for the lift but Teresa intercepts her.

Does she look like you, your daughter? Is she a scientist?

Dorothy She's a human rights campaigner.

Teresa sheepishly moves out of the way of the lift.

Teresa Who do I look like? Like this?- I was trying to imagine being you.

Dorothy Why?

Teresa To see what you see. When I came in just now you thought I was someone else. Was it an oompaloompa?

Dorothy I've told you before you look like a certain scientist.

Teresa Is that why you chose me?

Dorothy I really don't know.

Teresa Jesus. Do I look like you? A younger you?

Dorothy No, not at all. *[Indicating a book to Teresa]* Perhaps you should go ahead without me. Try to see things for yourself. I'm going to telephone my daughter.

Dorothy exits. Teresa tries to lights up a cigarette but her lighter is out of fuel. Though unseen, FSP encourages Teresa to look down the microscope where she sees a thread of DNA:

When Teresa takes her eye away a mysterious DNA performer (DNAP) appears.

Teresa Oh my God!

DNAP makes a spiral ascent and descent (possibly using rope or walking up an object or person), performing motifs for the bases at the centre of DNA.

Teresa ***[Reading from the book as Rosalind]*** My experiments show that the *[struggling]* Deoxy- Shit. Dorothy?! Deoxyribo- Dotty! – *[struggling on]* The deoxyribonucleic acid molecule, - DNA – no shit Dotty! - has two distinct forms. At extremely high humidities the fibre dramatically increases in length and

DNAP jumps from a high position to be caught by MSP.

may unexpectedly jump off the microscope stage transforming from the more ordered A form into the wet B form. The difference between their X-ray photographs is striking and so their exact water content is crucial.

We are in a colloquium at King's College London 1951

Watson *[from the audience]* Do you think she's pretty?

Wilkins *[next to Watson in the audience]* I prefer nice artistic women.

Teresa ***[as Rosalind presenting a lecture]*** To conclude, the sugar phosphate groups are located on the outside of the molecule like a backbone of sorts and the four bases stacked up like pennies on the inside. The 'X' shape on the B form photographs suggest a spiral structure, a helix.

Watson Gees! *[standing]* Ok. Timeout. Rosalind never said that!

Teresa Rosalind?

Watson There's no way she thought 'X' marked the spot.

Wilkins She was fiercely anti-helical.

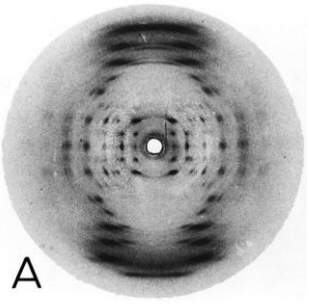
Watson Especially about the B form.

Teresa I'm just reading what it says here in her notes.

Wilkins *[To Watson though even looking at an 'ally' is difficult]* You don't think my preceding lecture on the helix could have prompted Rosalind to drop it from her presentation?

Teresa resuming as Rosalind I intend to *pro*ceed with a detailed analysis of the A form and disregard the B form for the present. As seen here the more promising A form gives significantly sharper and more plentiful bright spots. Any questions?

Watson ***[playing the game]*** I have a question.



Teresa as Rosalind Mr?

Watson Watson. Why don't you just build a model?

Teresa as Rosalind How exactly?

Wilkins Guess the shape.

Teresa as Rosalind Guess the shape!

Watson It'll take a millennium to analyse all the data you propose.

Teresa as Rosalind Which structure out of all the infinite possibilities do you suggest I 'guess at' first?

Watson The helix is very popular these days. You said just now-

Teresa as Rosalind I prefer a more thorough approach- let the data speak for itself.

Watson But-

Teresa as Rosalind Thank you all for your attention.

Watson Miss Franklin!- Miss Franklin wait. I have more questions.

Rosalind organises her equipment. DNAP climbs to a high place or alternatively draws up her rope whenever Watson approaches. Conversely she climbs down or lowers her rope for Rosalind.

Can I take you to lunch?

Wilkins Sadly women aren't permitted into the senior common room.

Watson There was a healthy collection of women in the lecture theatre just now.

Wilkins A good third of our department. *[To Watson only]* Coming?

Watson Where do you women eat?

Maurice Wilkins scarpers.

Well?

Silence.

I'll lunch with Maurice then.

Teresa as Rosalind You do as you wish. He clearly has nothing to do with me.

Watson So I hear. No one likes me here either - The American.

Teresa as Rosalind I'm sure it is nothing to do with your being American.

Watson Oh I bet they loved you in Cambridge. Let's trade departments. I'd be happy to stay here and help poor Maurice with DNA since you won't.

Teresa as Rosalind Why should I be his helper? It's my work.

Watson It was his suggestion you came to King's in the first place.

Teresa as Rosalind I doubt that.

Watson He wanted a real X-rays expert! He wanted your help.

Teresa as Rosalind Then why-

Watson He's shy. You terrify him.

Teresa as Rosalind Excuse me.

Watson *[Barring her way]* You cannot move cautiously when you're holding dynamite like DNA.

Teresa as Rosalind Stop bothering me Mr Watson.

Watson Dr Watson. I started early and got ahead.

Teresa as Rosalind Go back to Cambridge.

Watson I'll go back. You come and visit me next time.

Teresa as Rosalind Next time?!

Watson To see my model of DNA. I'll build a model in a week.

A small shared cabin on a boat travelling to the 2nd IUCr conference in Stockholm, 1952.

FSP, MSP and DNAP attach to Dorothy, Kathleen and Rosalind respectively like children under their feet. FSP and MSP form an alliance against DNAP who is amazing everyone with the quality of her dance. Dorothy is feeling rather seasick.

Dorothy Rosalind, these are quite possibly the best X-ray photographs I have ever seen.

Kathleen Yes there's definitely a missing spot on the fourth layer line. I'm afraid I don't have my Crystallography Tables with me. Could we please use your copy?

DNAP stops – suddenly nervous.

Don't look so stunned dear. I've done much of my best work in transit.

Teresa/Rosalind marvels at the Crystallography Tables, flicking through the pages.

Dorothy One always bumps into people at meetings but International Crystallography conferences are quite a different league. They often begin before one actually arrives.

Teresa as Rosalind Might you feel better on deck?

Kathleen Any ideas about the symmetry?

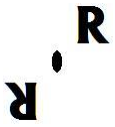
Teresa/Rosalind hands over the Crystallography Tables open at a specific page.

Dorothy But Rosalind! These two space groups are impossible.

Teresa as Rosalind So is it *[reading]* C2 then?

Kathleen It has to be.

Dorothy The key thing is two fold rotation.

FSP and MSP dance the Act 1 Scene 2 simple version of  *and develop it.*

Kathleen Extract all the data you can for a thorough analysis. That will limit the kind of model to build. Of course Dorothy here is the queen of the Patterson function. Unbelievable at it.

Teresa as Rosalind Will it tell us the structure?

Kathleen If you're very lucky. No one has ever performed a Patterson on one dimensional fibres like DNA have they?

Teresa as Rosalind I could achieve a real first then?

MSP lifts/launches DNAP up into the air but leaves her hanging there.

Dorothy With a lot of labour. Crick and Watson-

Teresa as Rosalind Crick?

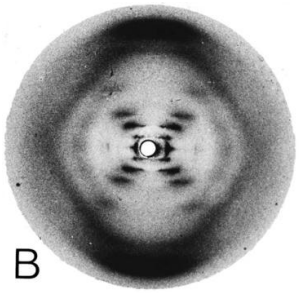
Dorothy Francis Crick, Max Perutz's mature PhD student. He's struck up a friendship with the new young man in the Cavendish lab - Jim Watson.

Teresa as Rosalind Oh yes.

Dorothy They asked my opinion on their theoretical case for a DNA helix.

MSP and FSP manipulate DNAP's body into awkward helix-like positions.

It certainly seemed plausible. But that was based on the diffraction photographs having a clearly defined ‘X’ pattern. Nothing like your photographs here.



Kathleen Except this one**.**

Teresa as Rosalind That must be the B form DNA.

Dorothy Could Crick and Watson have seen this?

Teresa as Rosalind Oh no. Although Watson has threatened to attempt a ridiculous model of it without a scrap of experimental evidence.

Kathleen How can he if DNA belongs to Kings?

Dorothy Molecules can’t belong to anyone. Collaborate.

The science performers conflict has got out of hand. The parent-like scientists exert their watchful power to ensure they ‘play nicely’.

Share the credit. That’s what we did with Vitamin B12.

Kathleen And I don’t doubt the two rival commercial companies viewed you colluding scientists as wholly unreliable.

Dorothy The important thing is not who solved the problem, but that the problem is solved.

Kathleen And verified. Persuading oneself of the rightness of a dubious solution has become an occupational disease among crystallographers these days, especially theorists, flattering themselves shamelessly that beauty is truth. But even theorists

must pass the test of peer approval. Have you indulged this Cambridge duo with an audience?

The Cavendish laboratory, Cambridge.

Teresa/Rosalind examines Crick and Watson's three chain model of DNA i.e. the three science performers frozen in an awkward clump.

Teresa as Rosalind Three main chains?! You've put your phosphates on the inside. Your bases are pointing outwards. Where is the water?

Watson There isn't any.

Teresa as Rosalind DNA is a thirsty molecule Mr Watson. Did you not listen to my lecture?

Crick Jim doesn't take notes do you Jim. But he will.

Teresa as Rosalind leaves the room but stays close by.

Lawrence Bragg Crick you're rocking the boat.

Watson I rocked it too Sir.

Lawrence Bragg Stop doing other people's crosswords. Dismantle this so-called model and hand over all the workshop bits to the King's people.

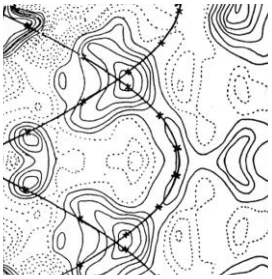
Watson They won't use them.

Lawrence Bragg The important thing is that you two don't attempt to use them. No more trespassing on King's territory.

Teresa as Rosalind exits.

Crick Sir Lawrence you do realise we aren't the only people 'trespassing on King's territory' as you say. They're not so precious on the other side of the pond. Linus Pauling may well beat us all once again. And so soon after his last triumph over your model of-

Lawrence Bragg Yes alright Crick. Why should I believe you? Prove that Pauling is working on DNA. When competition comes from more than one corner there is no need to hold back.



Rosalind's room at King's college.

Rosalind enters to find Watson struggling to make sense of the Patterson projection in her lab book in order to coax DNAP down and get hold of her.

Teresa as Rosalind What do you think you are doing?

Watson Waiting. Doesn't it look like I'm waiting? Two chains right? Two backbones? Everything in nature comes in pairs!

Teresa as Rosalind I think I'd like you to leave. Give me my lab book back.

Watson Relax. I came to show you Pauling's DNA manuscript.

Teresa as Rosalind Pauling! Pauling's a genius.

Watson That's why it's so funny. He has three chains. The same mistakes as me and Francis. Worse. Except everyone's too scared to tell him. He'll get there though if you don't hurry and use helical theory to interpret your photographs-

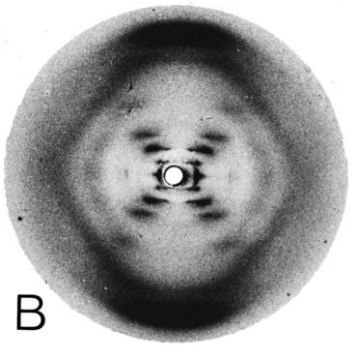
Watson suddenly manages to get hold of DNAP. Teresa as Rosalind charges at Watson who drops her lab book. Believing Rosalind is about to hit him Watson escapes to the outside corridor where he bumps into Maurice Wilkins.

I was just trying to help.

Distressed, Rosalind/Teresa packs a case and has her last moments with DNAP.

Wilkins Our dark lady leaves us next week. At last the decks will be clear and we can put all hands to the pump.

Wilkins shows Watson Rosalind's photograph of the B form DNA. Watson instantly recognises the significance of the 'X'.



Scene 2 Teresa's Art College. The Friday evening after Dorothy and Teresa's last meeting and a week since scene 1. Teresa's model has grown significantly.

Dorothy enters from the lift in her wheelchair, with a suitcase on her lap. Teresa surprises Dorothy by taking a Polaroid photograph of her as she enters. She is doubly surprised by a second photograph taken by a journalist with a 1960s camera.

Journalist 1 Mrs Hodgkin, how do you feel about being awarded this year's Nobel Prize for Chemistry?

Teresa Dotty! *This* year?

Journalist 1 1962.

Teresa Right.

Dorothy First I've heard of it I'm afraid.

Teresa Is it true? Was it for insulin?

The Nobel Award Ceremony 1962, the Royal Swedish Academy of Sciences.

FSP and MSP take their places in the front row of the auditorium as the crowned and robed king and queen of Sweden. All other participants are dressed in black tie.

Professor G. Hägg Your Majesties, Your Royal Highnesses, Ladies and Gentlemen.

It is abundantly clear that this year's prize-winners in chemistry have fulfilled the condition which Alfred Nobel laid down in his will; through their discoveries they have conferred the greatest benefit on mankind. After twenty-five years' labour, the protein goal has finally been reached. Today we honour the brilliant achievements of determining the structures of... myoglobin

Teresa What?! What's myoglobin?

Dorothy Haemoglobin's partner molecule. It enables oxygen to be stored in the muscles.

Professor G. Hägg and of course

Teresa Insulin!

Professor G. Hägg haemoglobin.

Teresa No!

Professor G. Hägg On behalf of the Swedish Academy I wish to extend our heartiest congratulations to Dr John Kendrew.

John Kendrew poses.

Teresa Who?!

Dorothy Max's PhD student and now colleague.

Professor G. Hägg and

Teresa She's here

Professor G. Hägg Dr Max Perutz

Max poses. John Kendrew and Max receive their Nobel from the King of Sweden.

Teresa You've made a mistake.

Dorothy It's perfectly correct Teri. John Kendrew beat both Max and I in your protein race.

Teresa What about that journalist?

Dorothy Someone must have got their wires crossed.

Teresa Wait there - they don't just give Nobel Prizes for Chemistry, do they? To work out insulin you need to mix up thinking from all over the shop- it's

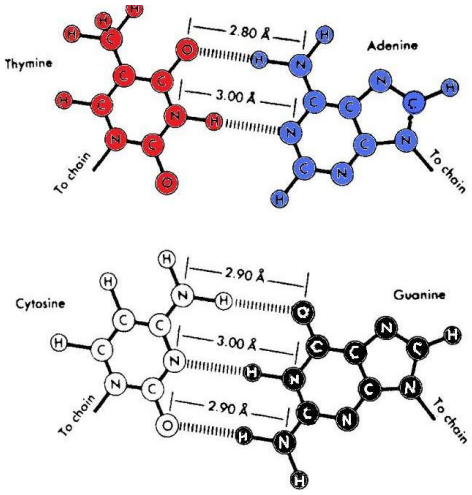
Dorothy Interdisciplinary?

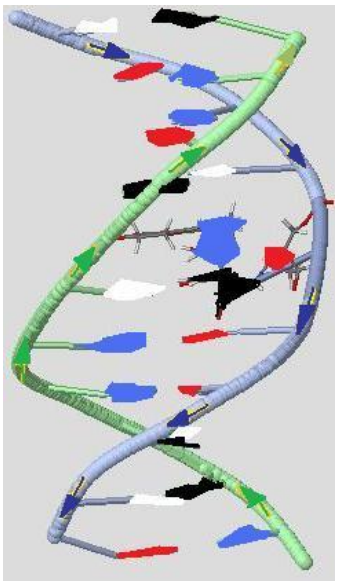
Teresa Course. Blatantly. What's the next category?

Professor A. Engström Your Majesties, Your Royal Highnesses, Distinguished Audience. An attempt to explain the significance of the following discovery could begin at a point which seems to be far from the precise world of biophysics and biochemistry. We could ask the question: How do we define a fine portrait or a good caricature - in which the individual *characteristics* of the person being portrayed are emphasized? The deoxyribonucleic acid molecule, DNA

Teresa Oh my God!

*DNAP and others jointly perform the concepts described here e.g. creating the staircase out of the four bases/the half-steps: **A**denine, **T**hymine, **G**uanine and **C**ytosine.*





Professor A. Engström *[Continuing on]* can be looked upon as two interwoven spiral staircases, forming one staircase with each banister progressing in opposite directions. The steps are formed by the paired bases. If each base, each half-step could be painted a different colour and if it were also possible for a person to climb this staircase, they would discover, that red is always coupled to blue, and black to white. The climber, who in molecules of human DNA has to ascend millions of steps, would see an endless variation in the sequence of steps they climb. This sequence contains a kind of message, the genetic code, which fundamentally determines the order of amino acids in a protein, a recipe which defines our characteristics.

Dorothy and Teresa marvel at the performers playing out a coded game where the triplets of bases in DNA translate into the amino acid beads in protein necklaces:

See Appendix

Teresa It's beautiful. So DNA designs all the different protein necklaces inside us!

Dorothy Can you crack the code now you can see the structure?

Teresa I can recognise bits of patterns that make me think of Kathleen say or you

but- Ok, there!

Dorothy Where?

Teresa There and then there! Three DNA bases in a row changes the next bead.

Dorothy How?

Teresa *[Reading the danced DNA sequence and relating it to the protein chain dance]* Red red red is a ring - the phenylalanine bead. Red red blue is really reactive! – cysteine. Red black blue is little glycine. So a sequence of three bases gives the code to make the next amino acid

Dorothy bead

Teresa in a protein necklace.

Dorothy Oh Teresa.

Teresa What have I done now?

Dorothy Truly excellent work.

Teresa Piece of piss once the patterns come out clearly.

Dorothy Whatever shapes one tries to pass on as new ideas, they must be substantiated through real life observations.

Teresa Didn't Rosalind substantiate the way we see DNA?

Dorothy No question.

Teresa Have you got your vintage dress in that suitcase?

Dorothy Teri

Teresa *[Rummaging through Dorothy's suitcase]* It's Rosalind.

Dorothy please don't expect- Whatever happens now I assure you Rosalind left her mark in the crystallographic community as a first class single-minded experimentalist.

Teresa Found it. Ta. Wow can I try this gold one?

Teresa puts on the gold dress, tidies her hair and practices curtsying in preparation to receive Rosalind's Nobel Prize.

Dorothy Rosalind never anticipated she would become more famous than any of us-

Professor A. Engström Dr. Francis Crick,

Crick poses

Dr. James Watson,

Watson poses

and Dr. Maurice Wilkins

Wilkins poses

Teresa What about Rosalind?

Professor A. Engström I ask you to receive this year's Nobel Prize for Physiology or Medicine from the hands of His Majesty the King.

Teresa tries to intercept the three men and receive the Nobel Prize from the king in their stead but fails.

Dorothy Please come away Teresa. Teri!

Teresa Four out of five Nobel winners today are Lawrence Bragg's Cambridge boys! Is Bragg on the Nobel selection committee? You should be raging.

Dorothy Don't be absurd.

Teresa It's a fix. Stop them! They've stolen Rosalind's Nobel!

Dorothy *[furious]* How dare you!

*Everything stops. Teresa is in shock***.**

You donkey!

Teresa is cut to the core, shaken and inconsolable by Dorothy's admonishment.

It's that sort of poor thinking that turned poor Rosalind into a feminist icon, worse still - a victim, worse still - a role model! She would have been appalled by any misguided movement to make her a martyr. At least the public had the excuse of being inflamed by Watson's caricature of her.

Teresa Watson's what?

Dorothy He wrote a popular book.

Watson There's a myth which is, you know, that Francis and I basically stole the structure from the people at King's. I was shown Rosalind Franklin's X-ray photograph and, Whoo! That was a helix, and a month later we had the structure, and Wilkins should never have shown me the thing.

I didn't go into the drawer and steal it, it was shown to me, and I was told the dimensions. We used her data to think about not to steal.

Teresa *[To Watson]* Do you think Rosalind should have shared your Nobel Prize?

Watson They don't give Nobel prizes for failure.

Crick *[Removing his jacket to reveal a brightly coloured waistcoat]* Well they don't give Nobel prizes to more than three people do they? What would happen to poor Maurice here? We solved DNA before he really had the freedom to get stuck in but he carried on working on it for another seven years just to verify our model was right.

Teresa *[To Crick]* Do *you* think Rosalind should have shared your Nobel Prize?

Crick ‘Should'! She was only two steps away from the solution.

Teresa Just two steps?

Crick She needed to realize that the bases were paired together – Jim cracked that, and that the two chains must run in opposite directions – that was obvious as soon as Max Perutz told me it could only be space group C2.

Teresa C2!

Crick *[Demonstrating like a magician, using two pencils, assisted by the dancers]* C2 means the two chains must look exactly the same when rotated by half a turn –they can't both point the same way (↑↑) because half a turn leaves them upside-down like this (↓↓). That's not the same as how we started is it? So it's wrong. Two chains can only work as C2 if one chain always runs up and the other always runs down, anti-parallel (↑↓). Like up and down escalators. Rotate by half a turn and-

Teresa they're exactly the same as how they started (↑↓). They appear to be.

Watson It's two fold rotation symmetry

Wilkins 'RR'

Teresa *[To Dorothy]* But Rosalind knew it was C2. We even discussed it together. Why didn't she see what it meant?

Crick Perhaps if she had trusted us more we might have pointed out the obvious.

Wilkins *[Intensely preoccupied - to Watson]* Concerning Rosalind,-

Watson Maurice discovered too late that the friction between him and Rosalind was inevitable. Both of them had been completely misled about each other's official roles working on DNA at King's. If they'd spoken a bit more I guess they might have at least worked that out - before she-

Wilkins *[to Watson]* Concerning Rosalind, is there any mention in your book that she died?

Teresa She died?!.. She couldn't have.

Dorothy Nobel Prizes are never awarded posthumously.

Teresa *[shocked/gutted]* No! Fuck.. fuck.. Jesus why?.. Bollocks.. Was it cancer? Because of all that X-ray radiation?

Crick It could have been genetic.

Teresa You fuckers! God not her.

Watson We all became friends once we'd each published our papers in *Nature*.

Teresa Fuckers!

Dorothy It's true Teri.

Teresa *[Taking off the dress]* Crystallography's all gone bad.

Dorothy Rosalind was much happier moving to Sage's department at Birkbeck.

Teresa Rosalind worked with Sage? Your Sage?!

Dorothy Jim and Francis became staunch defenders of her excellent but controversial virus work. Francis was quickly elevated to the rank of genius in her eyes. She wouldn't make a move without showing him all her results.

Teresa But they were at different universities.

Dorothy Crystallographers are good at floating. She adored Francis and his wife – a French artist.

Teresa Him?!

Dorothy She even stayed at their house to convalesce after her last cancer operation. I don't suspect Francis knew the details.

Crick Women's trouble of some sort apparently.

Teresa Did he ever tell her they used her data for their successful DNA model?

The Cricks' house. Cambridge 1958.

Crick What do you think you're doing out of bed? Come on. Odile's left strict instructions.

Teresa as Rosalind Don't bully Francis. I'll go back to my parents if you start fussing.

Crick Off you go then you obstinate mess.

Teresa as Rosalind I'm supposed to walk around.

Crick Your problem is you're rather too set on succeeding all by yourself and rather too stubborn to accept advice when it runs counter to your own ideas.

Teresa/Rosalind is unsteady.

Let me help.

[Crick carries Rosalind/Teresa to the 'bed'] There.

Teresa as Rosalind Do you think I would have solved DNA if Jim hadn't fired you up about it?

Crick DNA?! If Jim had been killed by a tennis ball I dare say poor Maurice might have solved it. With my help.

Teresa whacks him.

Who cares**!**

Teresa as Rosalind I would never have guessed Jim was serious about science in those tiny shorts!

Crick It's the molecule itself which really has style, quite as much as the scientists.

Teresa as Rosalind And how can you talk about style in that waistcoat.

Crick Unlike a great work of art or the jet engine which had to be invented, the DNA structure was always there. I was just lucky to be involved in the painting of its first picture.

Teresa as Rosalind Who got it isn't what matters.

Crick You have a good, hard, analytical mind, really first-class. But you lack intuition.

Teresa as Rosalind Facts are facts, Francis.

Crick Or mistrust it. Perhaps mistrust it.

Teresa as Rosalind Rubbish! I'll prove you wrong about that.

Crick Get better first.

Scene 3 Dorothy has on her gold frock for the Nobel Prize reply to the students 1964

Dorothy Your Majesties, Your Royal Highnesses, Students of Stockholm,

I was chosen to reply to you this evening as the one woman of our group, a position, which I hope very much will not be so very uncommon in future that it will call for any comment

Journalist 2 *[reporting]* The affable-looking housewife Mrs Hodgkin has won the Nobel Prize

Teresa When?!

Dorothy Sixty-four.

Journalist 2 *[continuing]* for a thoroughly unhousewifely skill-

Teresa She's a professor at Oxford too you dick.

Dorothy I hope there will be no need for future distinctions of this kind, as more use is made of the many gifts which women share equally with men.

Teresa You did it then. And it's just you! You don't even have to split the prize with anyone else.

Dorothy The only thing that could make this even better- perfect – would be if I could share the Nobel with Sage.

Teresa Why? It's for insulin isn't it? - Dorothy?

Dorothy *[returning to her speech]* I should not like to leave the impression that all structural problems can be settled by X-ray analysis or that all crystal structures are easy to solve. I seem to have spent much more of my life not solving structures than solving them.

Teresa Please tell me the Nobel was for insulin.

Dorothy The insulin data still didn't reveal the tiny changes in intensity that would tell us the phases.

Teresa Why?

Dorothy The equipment wasn't good enough.

Teresa Don't blame your-

Dorothy We put in a grant for £50,000 to buy the latest automatic diffractiometer, but so had my head of department, which was embarrassing. Sharing was out of the question. So we waited another year for an even better model and then another year for it to arrive, soaking the crystals in all sorts of reagents all the while trying to float the heavy atoms in - getting either no measurable changes or huge changes, or the crystals would just crumple completely. We were working with the best set of insulin crystals we had ever had, painstakingly prepared by a remarkable biochemist whose daughter had a particularly cruel type of diabetes. He used pig insulin that naturally contains zinc.

Teresa You killed pigs!! Look did you solve insulin's complete structure or not?

Dorothy Depends what you mean by complete.

Teresa You're so infuriating!

Dorothy Well, I really should be going soon.

Dorothy takes off her gold dress.

Teresa Don't Dorothy, I didn't mean-

Dorothy Can't miss my flight.

Teresa Why not? I dare you. What's so great about America?

Dorothy puts her dress in the suitcase and shuts it.

Dorothy The International Union of Crystallography Conference.

Teresa Well I'm sorry I'm not a crystalfrickinograper!

Dorothy Oh Teresa.

Teresa No. I really am. God I even tried to grow you a crystal by myself- a surprise present in one of the test tubes you left but it didn't work- I don't know why.

Dorothy Golly.

Teresa Why did you choose me?

Dorothy I didn't.

Teresa You must have had some reason

Dorothy You were just an apple that fell from the tree.

Teresa Oh Jesus.

Dorothy I think you chose me. You dared to take me on. Or rather you took on the portrait. You are very capable.

Teresa Fuck capable!

Dorothy Well that's why I'm going to give you this problem. It's all yours.

Teresa You can't just palm it off on me!

Dorothy starts to leave.

That's it is it? Fine. Fuck off then.

Dorothy Teresa.

Teresa You lead me on and then you- I don't get it, why don't you want to finish this?

Dorothy Please don't-

Teresa Define 'Crystallography' for me.

Dorothy It's a useful technique, an underlying science.

Teresa Which is it?

Dorothy It's- It's just a tool. I don't know - A piece of history.

Teresa Which?

Dorothy Both. It's all done automatically these days with computers. There are even robots to grow crystals for you.

Teresa *[Beginning to get/see Dorothy]* You resent that.

Dorothy Do I? Yes. Well - there will soon be no such thing as a real crystallographer.

Teresa So you're flying to America to have a conference on your own are you?!

Dorothy All sorts of researchers use crystallography as a formidable weapon to spy on diseases and so forth but the practice itself is essentially dead – the philosophy - the skill. These days everyone's a Molecular Biologist or a Structural Biologist or

Teresa They're just different words for the same thing.

Dorothy It's not the same. They don't care about 'seeing', or even thinking! - Witnessing the science through maps, revealing its hidden glory- sharing it all with other like-minded- The physical process of crystallographic discovery will soon be reduced to the push of a button – ignorant, joyless, no desire for perfection, to do serious things, no freedom for people like Sage or Kathleen or even Bragg to- Bragg, the father of– I don't know what it is now. Kathleen always wanted crystallography to be taught as a science in its own right, like chemistry. And poor Sage became- he became very wretched indeed, suffering from his disabled power to change the world.

Teresa With naive politics or science?

Dorothy The crystallographic community will soon be extinct. I pushed the computing and technology on and so I- Thomas was right. By wanting so desperately to help develop crystallography, I killed it. Now the only way I can keep it alive is by attempting a very poor imitation - your trivial model.

Teresa Tell you what, I'll hang a sign above it, shall I? Crystallography R. I. P. You crystafrickinfuckwit!

Dorothy I really should be-

Teresa How can you not see it?! Everything you've just said – it's so bloody obvious - the thing you're actually grieving for isn't crystallography at all. It's art!

Dorothy I imagine that's supposed to be a compliment.

Teresa That 'trivial' mess you think you hate, your chosen commission – it's bursting with fuckloads of complexity and symmetry and humanity. It's a blatant memorial to *your* art, your mind-blowing magical intuition – You.. donkey! You blind donkey!

Dorothy You can't charm me into finishing it Teri. I won't be complicit in placing the final piece of this particular puzzle. I thought perhaps you might discover another way forward but clearly-

Teresa You're terrified of the shape of things – what they will be-

Dorothy I wanted to pass something on – something ongoing - being immortalised as an oompaloompa wasn't quite what I had in mind. All those poor people.

Teresa Jesus Dorothy! Look at what's blatantly right in front of your face! - The shape of things now! All your work, your maps, the impact of everything you and your colleagues did to push crystallography has grown and grown and it's still growing! *Your* crystallography is alive as the underlying science behind tonnes of applications today. It *is* ongoing!! Celebrate that!

Dorothy If you mean by completing your-

Teresa *I mean* the portrait can never be finished!

At least two thousand members in the International Union of Crystallography you said – at the moment – that number will just go up and up because of more and more

researchers from shitloads of different fields whose work relies on what you lot did. Loads of people will use it who don't understand one f-ing bit of it! Totally clueless! No comprendo! Zilch! I think that's brilliant!

Dorothy How can you say that?

Teresa You're just like Kathleen don't you see?.. She might not have solved as many molecular structures as you, but didn't she contribute to every single structure that relied on using her Crystallography Tables? She did that work so other people like you could focus on new discoveries at the next level. Which you did. Yeah you struggled with insulin but you also solved some other incredible structures and more than that - *your* crystallography changed crystallography - changed the discovery of every single molecular structure since, each new drug, each person, each life.

Teresa's speech has stopped Dorothy in her tracks and shocked her into silence. Lost for words she is profoundly moved/upset/embarrassed.

It doesn't matter at all if you didn't manage to solve insulin.

Dorothy Oh really?

Teresa Totally – it's like a speck of icing on the biggest fuck off cake.

Dorothy Then do you promise not to hound me anymore about seeing insulin's structure?

Teresa Hound you!.. Ok. Fine. Yeah I do.

Dorothy Good. I left you a small leaving gift in your hammock by the way.

Teresa A gift?

Dorothy It was meant to be a surprise. I'll take it with me if you don't want it.

Teresa rushes to the hammock to find the gift and takes out a few pieces of paper.

Teresa No way! You drew this?

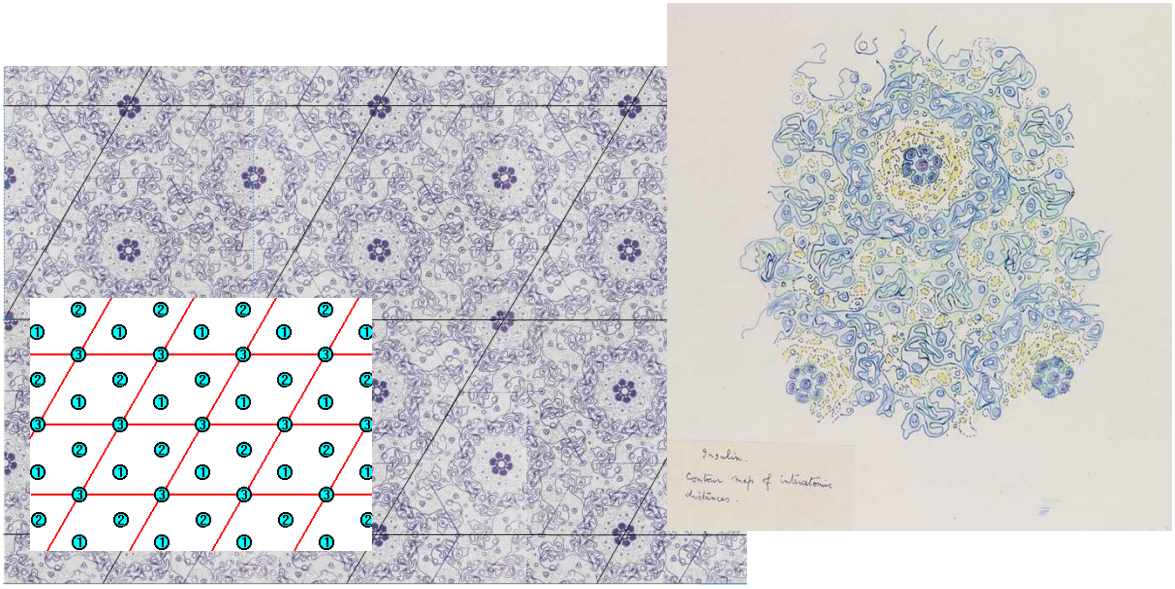
Dorothy It's just a very old map – when my hands weren't quite the disaster they are now.

Teresa Is this?. This isn't-?!. It's even more stunning than DNA.

Dorothy I used to believe each flower was a whole insulin molecule but actually there are six insulin molecules per 'flower'.

Teresa And six petals. Oh my God. That means each petal has four hundred and six atoms - plus a few hundred hydrogen atoms.

Dorothy As you can imagine you need much more detailed maps than this for the full structure.



Teresa Has anyone done it yet?

Dorothy Oh yes.

Teresa Who? Sorry. Forget it – you really don't have to answer that.

Dorothy It was a big group effort. None of them were even born when I took the first insulin photograph thirty-five years earlier!

Teresa 1969 then?

Dorothy August. They made three thousand extraordinary maps in total. Each map like a two-dimensional slice. When they stacked them all up on top of a light box, they could see all the contours in three dimensions. But first, the researchers had to trace all the contours on to thick transparent sheets.

Teresa All of them!

Dorothy Yes quite, so they persuaded their spouses and sisters and so on to come and help. Some even brought their children in with them.

Teresa Child labour?!

Dorothy Play! One big extended family. They put a huge playpen in the middle of the lab and hung baby bouncers in the doorways.

Teresa Right.

Dorothy I used to say that the evening I developed the first X-ray photograph I took of insulin was the most exciting moment of my life. But the Saturday afternoon, when we realised that the insulin electron density map was interpretable, runs that moment very close.

Teresa We?

Dorothy My brilliant group at Oxford.

Teresa Oh my God, I hate you!

Dorothy Teresa!

Teresa How could you do that to me?! You're a total and utter-

Dorothy Oompaloompa?

Teresa Yep, clearly. You did solve insulin!

Dorothy Oh no, it was my group. In those days it was all committees and visits and speeches for me. I merely raised grants for apparatus and tried to keep everyone going. Of course I couldn't help being thoroughly invasive about everything they were up to. We colluded with Max Perutz's latest Cambridge recruits whose new rotation and translation functions confirmed that insulin has a two fold axis

Teresa 'RR'

Dorothy perpendicular to the three fold axis

Teresa 'RRR'

Dorothy We also knew that each molecule in our pig insulin crystals contained two zinc atoms.

Teresa - which could act as heavy atoms!

Dorothy It was certainly a very helpful start. Where do you think two zinc atoms must go in an 'RRR' molecule so that they don't destroy the symmetry?

Teresa Hang on.

FSP, MSP and DNAP rush to help Teresa work it out through their dancing.

Oh my God - in the middle! Directly on top of each other and in the middle.

Dorothy Perfect.

Teresa I don't believe your group solved insulin entirely without you. Not once you saw you could interpret the maps. And you know maps. You're the wizard. Could they have done it without you? Could you have resisted?

Dorothy For one glorious week, I returned to full time research and helped my group build the insulin model.

Dorothy gets up.

Teresa No! Jesus you can't leave it there. Show me. - Sorry. Forget it. I said nothing. You mustn't miss your flight.

Dorothy It does really matter to you I think – 'getting' it - every detail in place.

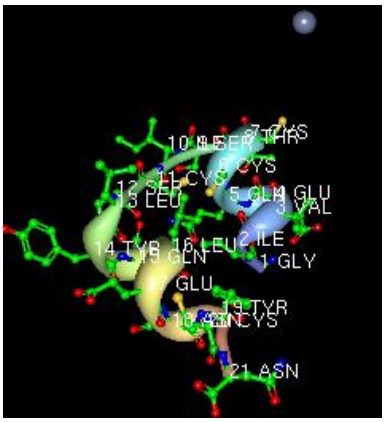
Teresa There are some things I just want to know. Layers of detail and finding different ways in, makes things more beautiful. And awesome/frightening. And familiar. And real. Which is kindof reassuring. I don't mean to hound you. Stay.

Dorothy We've still a few minutes before my daughter's due to whisk me away. Perhaps it might be an idea to try to- *[emotional]* let's try our best to-

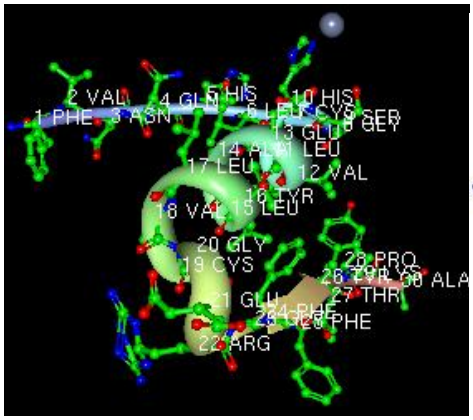
Teresa See the complete structure together?

Dorothy Yes that.

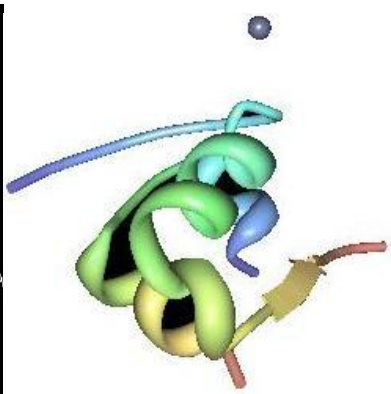
Dorothy guides Teresa through the dance of seeing and modelling insulin's 'complete' structure:



Top view A chain

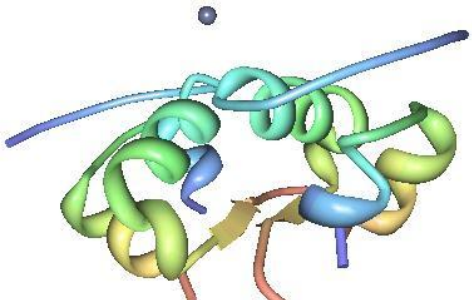


Top view B chain

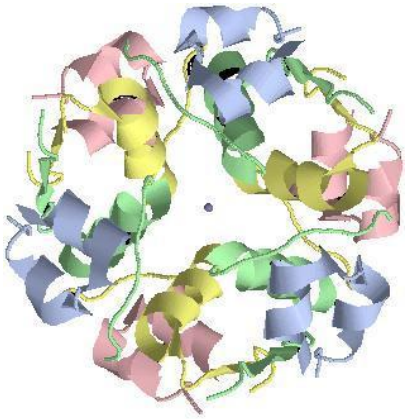


1 monomer/molecule is the A chain + B chain

The chains above are the 'bendy'/folded versions of the linked straight line chains A and B on p. 105

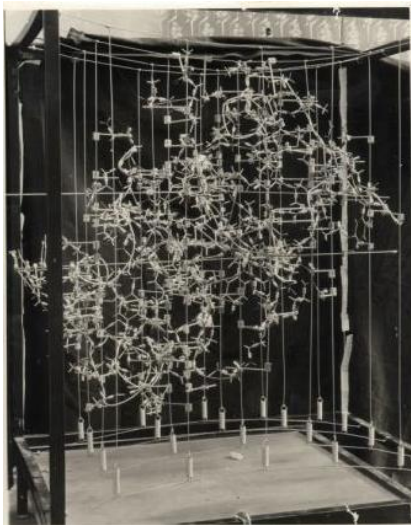


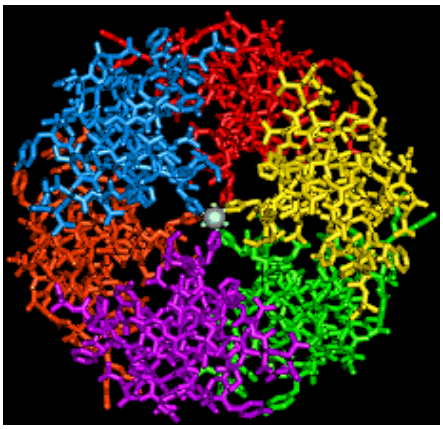
1 dimer is 2 monomers



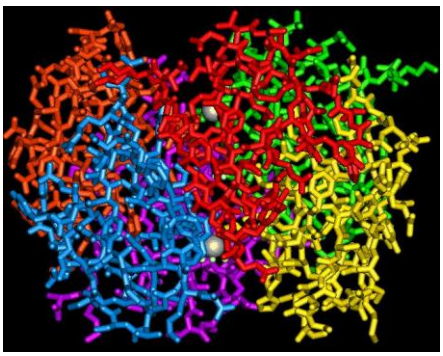
1 hexamer is 3 dimers is 6 monomers/ molecules

Dorothy's model of an insulin hexamer





Top view of hexamer



Side view of hexamer

- NB/ The large ball in the pictures represents a zinc atom – it is actually 2 zinc atoms directly on top of each other as is seen in the side views of the hexamer

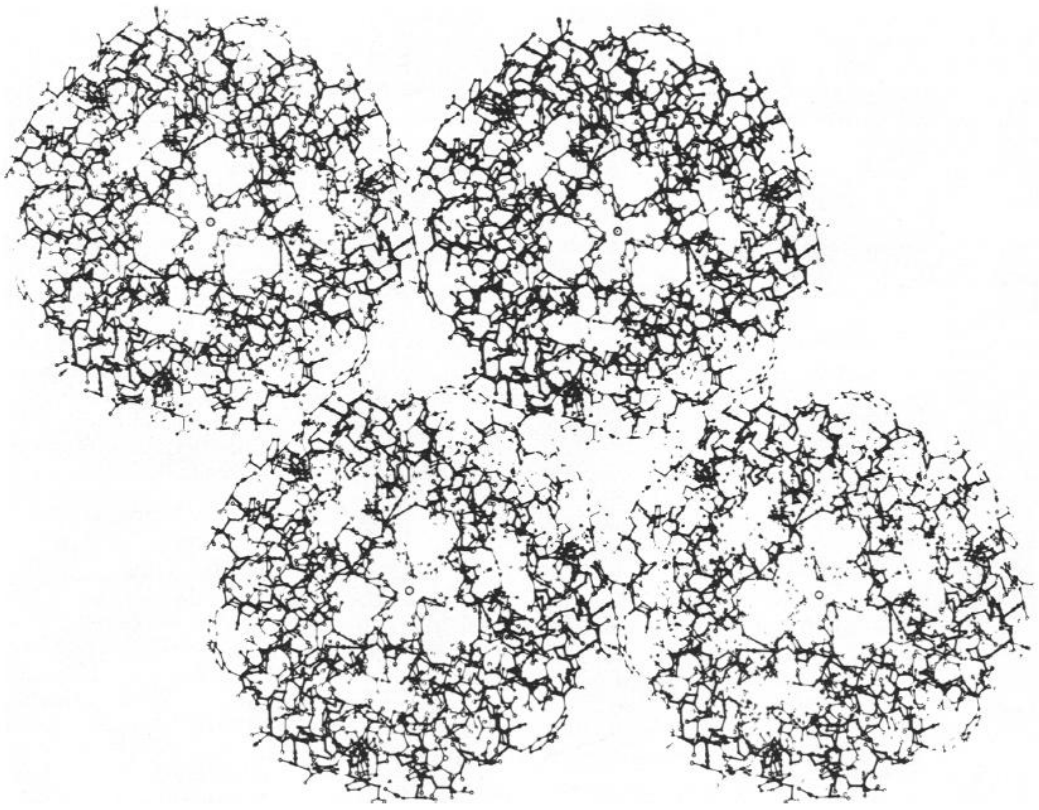


Figure 13. The packing of the hexamers in the rhombohedral crystal.

A handwritten note is projected:

"3.8.69 late night news from Dorothy Hodgkin: INSULIN IS SOLVED! Gone to Oxford to help celebrate – Max Perutz"

Then one last fact:

Dorothy continued to refine her work on the structure of insulin until 1988 when she knew the position, attractions and interactions of

every

last

atom.

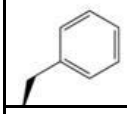
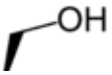
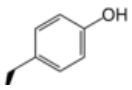
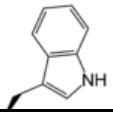
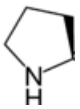
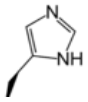
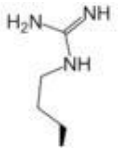
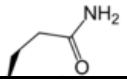
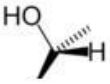
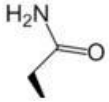
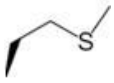
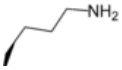
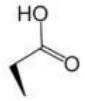
The End

Appendix THE GENETIC CODE translates a long list of triplets of three bases into a sequence of amino acids in a protein necklace. Each amino acid side chain is shown.

i.e. TTT or TTC is PHE phenylalanine TGT or TGC is CYS cysteine TGT, TGC, TGA or TGG is GLY glycine

TTA, TTG, CTT, CTC, CTA or CTG is LEU leucine ATA or ATG starts sequence TAA, TGA or TAG ends it

SECOND BASE IN TRIPLET

FIRST BASE IN TRIP-LET	Thymine	Cytosine	Adenine	Guanine	**THIRD** BASE IN TRIP-LET
T	PHE phenylalanine 	SER serine 	TYR tyrosine 	CYS cysteine 	**T**
					C
	LEU leucine 		Stop	stop	**A**
			stop	TRP tryptophan 	**G**
C	LEU	PRO proline 	HIS histidine 	ARG arginine 	**T**
					C
			GLN glutamine 		**A**
					G
A	ILE isoleucine 	THR threonine 	ASN asparagine 	SER (above)	**T**
					C
	MET methionine  + start		LYS lysine 	ARG (above)	**A**
					G
T	VAL valine 	ALA alanine 	ASP aspartic acid 	GLY glycine Nothing – i.e. just a single hydrogen atom	**T**
					C
			GLU glutamic acid 		**A**
					G