

# Science

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# Chapter 1

## Feibelman, 2011. *A PhD Is Not Enough!: A Guide to Survival in Science*

### Amazon/A PhD Is Not Enough!: A Guide to Survival in Science by Peter J. Feibelman

“Everything you ever need to know about making it as a scientist<sup>1</sup>.

Despite your graduate<sup>2</sup> education<sup>3</sup>, brainpower<sup>4</sup>, & technical<sup>5</sup> prowess<sup>6</sup>, your career<sup>7</sup> in scientific<sup>8</sup> research<sup>9</sup> is far from

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<sup>1</sup>**scientist** [n] a person who studies 1 or more of the natural sciences

<sup>2</sup>**graduate** [n] **1.** a person who has successfully completed a course of study, especially a person who has a 1st university degree; **2.** (*North American English*) a person who has completed their high school studies; [v] **1.** [intransitive, transitive] to get a degree, especially your 1st degree, from a university or college; **2.** [intransitive, transitive] (*North American English*) to complete a course in education, especially at high school; **3.** [intransitive] **graduate (from something) to something** to start doing something more difficult or important than what you were doing before.

<sup>3</sup>**education** [n] **1.** [uncountable, singular] a process of teaching, training & learning, especially in schools or colleges, to improve knowledge & develop skills; **2.** [uncountable] a particular kind of teaching or training; **3.** (**Education**) [uncountable] the institutions or people involved in teaching & training; **4.** (usually **Education**) [uncountable] the subject of study that deals with how to teach.

<sup>4</sup>**brainpower** [n] [uncountable] the ability to think; intelligence.

<sup>5</sup>**technical** [a] **1.** [usually before noun] connected with the use of science or technology; involving the use of machines; **2.** [usually before noun] connected with a particular type of activity, or the skills & processes needed for it; **3.** [usually before noun] (of language, writing or ideas) requiring knowledge & understanding of a particular subject; **4.** connected with the details of a law or set of rules.

<sup>6</sup>**prowess** [n] [uncountable] (*formal*) great skill at doing something.

<sup>7</sup>**career** [n] **1.** the period of time that you spend in your life working or doing a particular thing; **2.** the series of jobs that a person has in a particular area of work, usually involving more responsibility as time passes.

<sup>8</sup>**scientific** [a] [usually before noun] **1.** involving science; connected with science; **2.** done in a careful & organized way, SYNONYM: **methodical**.

<sup>9</sup>**research** [n] [uncountable] careful study of a subject, especially in order to discover new facts or information about it. The plural form **researches** is also sometimes used in British English, but is much less frequent.; [v] **1.** [transitive, intransitive] to study something carefully & try to discover new facts about it; **2.** [transitive] to collect information for an article, a book, etc.

assured<sup>10</sup>. Permanent<sup>11</sup> positions<sup>12</sup> are scarce<sup>13</sup>, science<sup>14</sup> survival<sup>15</sup> is rarely<sup>16</sup> part of formal<sup>17</sup> graduate training<sup>18</sup>, & a good mentor<sup>19</sup> is hard to find.

In *A Ph.D.<sup>20</sup>. Is Not Enough!*, physicist<sup>21</sup> PETER J. FEIBELMAN lays out<sup>22 23</sup> a rational<sup>24</sup> path<sup>25</sup> to a fulfilling<sup>26</sup> long-term<sup>27</sup> research career. He offers sound<sup>28</sup> advice<sup>29</sup> on selecting<sup>30</sup> a thesis<sup>31</sup> or postdoctoral<sup>32</sup> adviser<sup>33</sup>; choosing among

<sup>10</sup>**assured** [a] **1.** certain to happen; **2. assured of something** (of a person) certain to get something; **3.** showing confidence in yourself & your abilities.

<sup>11</sup>**permanent** [a] lasting for a long time or for all time in the future; existing all the time, OPPOSITE: **temporary**.

<sup>12</sup>**position** [n] **1.** [countable] the place where somebody/something is located; **2.** [uncountable] the place where somebody/something is meant to be; the correct place; **3.** [countable, uncountable] (**in/into a position**) the way in which somebody is sitting or standing; the way in which something is arranged; **4.** [countable, usually singular] the situation that somebody is in, especially when it affects what they can & cannot do, SYNONYM: **situation**; **5.** [countable] an opinion on or attitude towards a particular subject; **6.** [countable, uncountable] **position (of somebody/something)** the level of importance of a person, organization or thing when compared with others, SYNONYM: **status**; **7.** [countable] a job, SYNONYM: **post**; **8.** [countable] a place in a race, competition or test, when compared with others; [v] **1.** to put somebody/something in a particular position; **2.** [often passive] to put somebody/something in a particular situation, especially when it affects what they can & cannot do; **3.** to advertise a product, service or business as satisfying the needs of a particular group of customers.

<sup>13</sup>**scarce** [a] (**scarcer, scarcest**) if something is scarce, there is not enough of it & it is only available in small quantities.

<sup>14</sup>**science** [n] **1.** [uncountable] knowledge about the structure & behavior of the natural & physical world, based on facts that you can prove, e.g. by experiments; **2.** [uncountable] the study of science; **3.** [countable, uncountable] a particular branch of science, especially biology, chemistry or physics; **4.** [singular] **science of something** a system for organizing the knowledge about a particular subject; **not an exact science** [idiom] used to describe an activity that is based partly on guessing & opinions, not only on accurate measurements & set rules.

<sup>15</sup>**survival** [n] **1.** [uncountable] the state of continuing to live or exist, often despite difficulty or danger; **2.** [countable] **survival (of something)** something that has continued to exist from an earlier time, SYNONYM: **relic**; **the survival of the fittest** [idiom] the idea that only the people or things that are best adapted to their surroundings will continue to exist.

<sup>16</sup>**rarely** [adv] not often.

<sup>17</sup>**formal** [a] **1.** following strict rules of how to do something; suitable for an official occasion, OPPOSITE: **informal**; **2.** (of speech or writing) suitable for official or series situations, OPPOSITE: **informal**; **3.** (of education or training) received in a school, college or university rather than gained just through practical experience, OPPOSITE: **informal**; **4.** concerned with the form of the structure of something rather than its content; **5.** concerned only with following rules.

<sup>18</sup>**training** [n] [uncountable] the process of learning the skills that you need to do a job.

<sup>19</sup>**mentor** [n] **1.** an experienced person who advises & helps somebody with less experience over a period of time; **2.** an experienced person in a company, university, etc. who trains & advises new employees or students.

<sup>20</sup>**PhD** [n] (*also Ph.D. especially in North American English*) a university degree of a very high level that is given to somebody who has done research in a particular subject (abbr., for 'Doctor of Philosophy').

<sup>21</sup>**physicist** [n] a scientist who studies physics.

<sup>22</sup>**lay out** [phrasal verb] **lay somebody ↔ out 1.** to knock someone unconscious; **2.** to prepare a dead body to be buried; **lay something ↔ out 1.** to spread something out so that it can be seen easily or is ready to use; **2.** [often passive] to plan how something should look & arrange it in this way; **3.** to present a plan, an argument, etc. clearly & carefully, SYNONYM: **set something ↔ out**; **4.** (*informal*) to spend money, SYNONYM: **fork out (for something)**.

<sup>23</sup>**layout** [n] [usually singular] the way in which the parts of something such as the page of a book, a garden, or a building are arranged.

<sup>24</sup>**rational** [a] **1.** (of behavior or ideas) based on reason rather than emotions, OPPOSITE: **irrational**; **2.** (of a person) able to think clearly & make decisions based on reasons rather than emotions, SYNONYM: **reasonable**; OPPOSITE: **irrational**.

<sup>25</sup>**path** [n] (plural **paths**) **1.** a way or track that is built or is made by the action of people walking; **2.** [usually singular] a line along which somebody/something moves; the space in front of somebody/something as they move; **3.** (also **pathway**) a way of achieving something; **4. path (to something)** (*computing*) the logical location of a file or directory.

<sup>26</sup>**fulfil** [v] (*British English*) (*North American English fulfill*) **1. fulfil something** to do or have what is required or necessary; **2. fulfil something** to have a particular role or purpose; **3. fulfil something** to do or achieve what has hoped for or expected.

<sup>27</sup>**long-term** [usually before noun] **1.** that will last or have an effect over a long period of time into the future; **2.** that has lasted a long time & is not likely to change or be solved quickly.

<sup>28</sup>**sound** [n] **1.** [countable] something that can be heard; **2.** [uncountable] continuous movements (called **vibrations**) that travel through air or water & can be heard when they reach a person's or an animal's ear; **3.** [uncountable] what you can hear coming from a television, radio, etc., or as part of a film; [v] (not usually used in the progressive tenses) **1. linking verb** to give a particular impression when heard or read about. In spoken English, people often use **like** instead of **as if** or **as though** in this meaning. This is not correct in academic English. **Like** can be used before a noun phrase but not before a clause.; **2. (-sounding)** (in adjectives) giving the impression of being something; **3.** [intransitive, transitive] to give a signal such as a warning by making a sound; **4.** [transitive] to express a particular opinion about a situation or idea; [a] (**sounder, soundest**) **1.** sensible; that can be relied on & that will probably give good results; **2.** in good condition; not damaged or hurt; **3.** [only before noun] good & thorough.

<sup>29</sup>**advice** [n] [uncountable] an opinion or a suggestion about what somebody should do in a particular situation.

<sup>30</sup>**select** [v] **1.** to choose somebody/something from a group of people or things, usually according to a system; **2. select something (from something)** to mark something on a computer screen for a particular purpose; to choose something on a computer screen, especially from a menu; **select for/against something** (*biology*) (in terms of evolution) [phrasal verb] to be the deciding factor in whether a particular living thing or characteristic of a living thing survives; [a] [only before noun] carefully chosen as the best out of a larger group of people or things.

<sup>31</sup>**thesis** [n] (plural **theses**) **1.** a statement or an opinion that is discussed in a logical way & presented with evidence in order to prove that is true; **2. thesis on something** a long piece of writing completely by a student as part of a university degree, based on their own research.

<sup>32</sup>**postdoctoral** [a] [usually before noun] connected with advanced research or study that is done after a PhD has been completed.

<sup>33</sup>**adviser** [n] (*also advisor*) a person who gives advice, especially somebody who knows a lot about a particular subject.

research jobs in academia<sup>34</sup>, government<sup>35</sup> laboratories<sup>36</sup>, & industry<sup>37</sup>; preparing<sup>38</sup> for an employment<sup>39</sup> interview<sup>40</sup>; & defining<sup>41</sup> a research program<sup>42 43</sup>. The guidance<sup>44</sup> offered<sup>45 46</sup> in *A Ph.D. Is Not Enough!* will help you make your oral<sup>47</sup> presentations<sup>48</sup> more effective<sup>49</sup>, your journal<sup>50</sup> articles<sup>51</sup> more compelling<sup>52</sup>, & your grant<sup>53</sup> proposals<sup>54</sup> more successful<sup>55</sup>.

A classic guide for recent & soon-to-be graduates, *A Ph.D. Is Not Enough!* remains required reading for anyone on the

<sup>34</sup>**academia** [n] (also **academe**) [uncountable] the world of research & education at universities, & the people involved in it.

<sup>35</sup>**government** [n] **1.** [countable + singular or plural verb, uncountable] (often **the Government**) (abbr., **govt**) the group of people & the institutions connected with them that are responsible for controlling a country or state; **2.** [uncountable] a particular system or method of controlling a country; **3.** [uncountable] the activity or manner of controlling a country.

<sup>36</sup>**laboratory** [n] (plural **laboratories**) (also *informal lab*) a room or building containing equipment for scientific experiments, research or teaching, or for making drugs or chemicals.

<sup>37</sup>**industry** [n] (plural **industries**) **1.** [countable] the people & activities involved in producing a particular thing, or in providing a particular service; **2.** [uncountable] the production of goods from raw materials, especially in factories; **3.** [uncountable] (*formal*) the quality of working hard.

<sup>38</sup>**prepare** [v] **1.** [transitive] to make something/somebody ready to be used or to do something; **2.** [intransitive, transitive] to make yourself ready to do something or for something that you expect to happen; **3.** [transitive] **prepare something** to make food ready to be eaten; **4.** [transitive] **prepare something (from something)** to make a medicine or chemical substance, e.g. by mixing other substances together; **prepare the ground (for something)** [idiom] to make it possible or easier for something to happen or to be achieved.

<sup>39</sup>**employment** [n] [uncountable] **1.** work, especially when it is done to earn money; the state of being employed; **2.** the situation in which people have work; the number of people who have work in a country or area, OPPOSITE: **unemployment**; **3.** **employment (of somebody)** the act of employing somebody; **4.** **employment (of something)** the use of something.

<sup>40</sup>**interview** [n] **1.** a private meeting between people when questions are asked & answered; **2.** a conversation in which somebody, especially a famous person, is asked questions by a journalist in order to find out about their work & opinions & that is printed in a newspaper, shown on television, etc.; **3.** a formal meeting at which somebody is asked questions to see whether they are suitable for a particular job, or for a course of study at a college, university, etc.; **4.** **interview (with somebody)** a formal meeting at which somebody is asked questions about a crime by the police; [v] **1.** [transitive] to ask somebody questions at a private meeting; **2.** [transitive] **interview somebody (about something)** to ask somebody questions about their life, opinions, etc., especially on the radio or television or for a newspaper or magazine; **3.** [transitive] **interview somebody (for something)** to talk to somebody & ask them questions at a formal meeting in order to find out whether they are suitable for a job, course or study, etc.; **4.** [intransitive] **interview (for something)** (*especially North American English*) to talk to somebody & answer questions at a formal meeting in order to get a job, a place on a course of study, etc.

<sup>41</sup>**define** [v] **1.** to describe or show exactly the nature or extent of something; **2.** to say or explain what the meaning of a word or phrase is; **3.** to form or establish the essential character of something; **4.** **define something** to show clearly the outline or position of something.

<sup>42</sup>**program** [n] **1.** (*computing*) a set of instructions in code that control the operations or functions of a computer; **2.** (*North American English*) = **programme**; [v] **1.** to give a computer, etc. a set of instructions to make it perform a particular task; **2.** (*North American English*) = **programme**.

<sup>43</sup>**programme** [n] (*British English*) (*North American English program*) **1.** a plan or things that will be done or included in the development of something; **2.** something that people watch on television or listen to on the radio; **3.** **programme (of something)** an organized order of performances or events; **4.** (*North American English*) a course of study; [v] (*British English*) (*North American English program*) [usually passive] to make a person, an animal, etc. behave in a particular way, so that it happens automatically.

<sup>44</sup>**guidance** [n] [uncountable] **1.** help or advice that is given to somebody, especially by somebody in authority; **2.** the process of controlling the direction or position of something using special equipment.

<sup>45</sup>**offer** [v] **1.** [transitive] to give or provide something; **2.** [transitive] to say that you are willing to give something to somebody or to do something for somebody; **have something to offer** [idiom] to have something available that somebody wants.

<sup>46</sup>**offer** [n] **1.** an act of saying that you are willing to do something for somebody or give something to somebody; **2.** **offer (of something)** an amount of money that somebody is willing to pay for something; **3.** a reduction in the normal price of something, usually for a short period of time; **on offer** [idiom] that can be bought, used, etc.

<sup>47</sup>**oral** [a] **1.** [usually before noun] spoken rather than written, OPPOSITE: **written**; **2.** [only before noun] connected with the mouth.

<sup>48</sup>**presentation** [n] **1.** [countable, uncountable] the act of showing or offering information or ideas for other people to consider; an occasion when this happens; **2.** [countable, uncountable] **presentation of something** the way that somebody/something is shown or described; **3.** [uncountable] the act of giving or showing something to somebody in a formal situation; **4.** [countable, uncountable] (*medical*) the way that a condition or patient is or appears; the occasion when a condition or patient is seen or examined.

<sup>49</sup>**effective** [a] **1.** producing the result that is wanted or intended; producing a successful result, OPPOSITE: **ineffective**; **2.** [only before noun] real or actual, although not official intended; **3.** (of laws & rules) in use.

<sup>50</sup>**journal** [n] **1.** a newspaper or magazine that deals with a particular subject or profession; **2.** a written record of the things you do or see every day.

<sup>51</sup>**article** [n] **1.** a piece of writing about a particular subject in a newspaper, magazine or journal; **2.** (*law*) a separate item in a legal document, agreement or contract; **3.** **article (of something)** (*formal*) a particular item, object or separate thing, especially 1 of a set, SYNONYM: **item**; **4.** (*grammar*) the words *a* & *an* (**the indefinite article**) or *the* (**the definite article**); **article of faith** [idiom] something that you believe very strongly, as if it were a religious belief.

<sup>52</sup>**compelling** [a] **1.** that makes you think it is true or valid; **2.** making you pay attention through being so interesting & exciting; **3.** that cannot be resisted.

<sup>53</sup>**grant** [v] **1.** [often passive] to agree to give somebody what they ask for, especially formal or legal permission to do something; **2.** **grant (that)** ... to admit that something is true, although you may not like or agree with it; [n] **1.** [countable] a sum of money given by a government or other organization for a particular purpose; **2.** [uncountable] **grant (of something) (to somebody)** the action of granting something.

<sup>54</sup>**proposal** [n] **1.** a formal suggestion or plan; **2.** **proposal (that ...)** an explanation suggested for people to consider.

<sup>55</sup>**successful** [a] **1.** achieving your aims or what was intended, OPPOSITE: **unsuccessful**; **2.** having become popular &/or made a lot of money.

threshold<sup>56</sup> of a career in science. This new edition<sup>57</sup> includes 2 new chapters<sup>58</sup> & is revised & updated<sup>59</sup> throughout<sup>60</sup> to reflect<sup>61</sup> how the revolution<sup>62</sup> in electronic communication<sup>63</sup> has transformed<sup>64</sup> the field.”

## Editorial Reviews

### Review

- “It took me over 40 years to learn from experience what can be learned in 1 hour from this guide.” – Carl Djerassi
- “Breezily<sup>65</sup> written, irreverent<sup>66</sup>, & filled with useful information<sup>67</sup>. I wish something like it had been available<sup>68</sup> when I was starting out.” – Michael Weber, Cancer Center Director, University of Virginia, Charlottesville
- “I loved *A PhD Is Not Enough!* I couldn’t put it down. His writing is delightful<sup>69</sup>, & he is on target<sup>70</sup> with virtually<sup>71</sup> all of his advice.” – Steven H. Strogatz, author of *The Joy of X*

### About the Author

“A Senior Scientist at Sandia National Laboratories, PETER J. FEIBELMAN received a Ph.D. in Physics from the University of California at San Diego, did postdoctoral research at the C.E.N. Saclay (France) and the University of Illinois (Urbana), and taught for three years at Stony Brook University. Feibelman lives in Albuquerque, New Mexico.”

## Preface: What This Book Is About

“My scientific career almost never happened. I emerged<sup>72</sup> from graduate school with a PhD & excellent<sup>73</sup> technical skills but with little understanding of how to survive in science. In this, I was not unusual<sup>74</sup>. Survival skills are rarely part of the graduate curriculum<sup>75</sup>. Many professional scientists believe<sup>76</sup> that “good” students find their way on their own, while

<sup>56</sup>**threshold** [n] **1.** [countable] the level at which something starts to happen or have an effect; **2.** [singular] the point just before a new situation or period begins.

<sup>57</sup>**edition** [n] **1.** (abbr., **ed.**) **edition (of something)** the total number of copies of a book, newspaper or magazine published at 1 time; **2.** the form in which a book is published.

<sup>58</sup>**chapter** [n] **1.** (abbr., **chap.**) a separate section of a book, usually with a number or title; **2.** a period of time in history or a person’s life.

<sup>59</sup>**update** [v] **update something** to get or give somebody the most recent information about something; to add the most recent information to something; [n] **update (on something)** a report that gives the most recent information about something; a new version of something containing the most recent information.

<sup>60</sup>**throughout** [prep, adv] **1.** in or into every part of something; **2.** during the whole period of time of something.

<sup>61</sup>**reflect** [v] **1.** [transitive] to show or be a sign of what something is like or how somebody thinks or feels; **2.** [transitive] to throw back light, heat, sound, etc. from a surface; **3.** [intransitive, transitive] to think carefully & deeply about something.

<sup>62</sup>**revolution** [n] **1.** [countable, uncountable] a great change in conditions, ways of working, beliefs, etc. that affects large numbers of people; **2.** [countable, uncountable] an attempt, by a large number of people, to change the government of a country, especially by violent action; **3.** [countable, uncountable] a complete circular movement around a point.

<sup>63</sup>**communication** [n] **1.** [uncountable] the activity or process of expressing ideas & feelings or of giving people information. In business, **communication** often describes the activity or process of giving information to the public, e.g. in commercials.; **2.** [uncountable] (**communications** [plural]) methods of sending information, especially telephones, radio, computers, etc.; **3.** (**communications**) [plural] methods of traveling or transporting goods, such as roads & railways; **4.** [countable] a message, letter, email or telephone call.

<sup>64</sup>**transform** [v] **1.** **transform something/somebody (from something) (into/to something)** to change the form of something/somebody, SYNONYM: **convert**; **2.** **transform something/somebody** to completely change the appearance or character of something/somebody, especially so that it is better; **3.** **transform something (into/to something) (mathematics)** to change a shape, expression or function by transformation.

<sup>65</sup>**breezily** [adv] in a cheerful & relaxed way.

<sup>66</sup>**irreverent** [a] (*usually approving*) not showing respect to somebody/something that other people usually respect.

<sup>67</sup>**information** [n] [uncountable] **1.** facts or details about somebody/something that are provided or learned; **2.** data that are stored, analyzed or passed on by a computer; **3.** what is shown by a particular arrangement of things.

<sup>68</sup>**available** [a] **1.** (of things) that you can use or obtain, OPPOSITE: **unavailable**; **2.** **available (for something)** (of a person) free or willing to do something, OPPOSITE: **unavailable**.

<sup>69</sup>**delightful** [a] very pleasant, SYNONYM: **charming**.

<sup>70</sup>**NQBH: targeted?**

<sup>71</sup>**virtually** [adv] **1.** almost or very nearly, so that any slight difference is not important; **2.** by the use of computer software that makes something appear to exist; **3.** by means of computers & computer networks.

<sup>72</sup>**emerge** [v] **1.** [intransitive, transitive] (of facts or ideas) to become known; **2.** [intransitive] to start to exist or appear; **3.** [intransitive] **emerge (from something) (into something)** to come out of a dark or hidden place; **4.** [intransitive] **emerge (from something)** to survive a difficult situation or experience.

<sup>73</sup>**excellent** [a] extremely good.

<sup>74</sup>**unusual** [a] different from what is usual or normal, SYNONYM: **uncommon**.

<sup>75</sup>**curriculum** [n] (plural **curricula**) the subjects that are included in a course of study or taught in a school, college or university.

<sup>76</sup>**believe** [v] (not used in the progressive tenses) **1.** [often passive] to think that something is true or possible, although you are not completely certain; **2.** to feel certain that something is true or that somebody is telling the truth; **believe in somebody/something** [phrasal verb] to feel certain that somebody/something exists; **believe in somebody** [phrasal verb] to feel that you can trust somebody &/or that they will be successful; **believe in something** [phrasal verb] to think that something is good, right or acceptable.



the remainder<sup>77</sup> cannot be helped. This justifies<sup>78</sup> neglect<sup>79</sup> &, perhaps not incidentally<sup>80</sup>, reduces work load<sup>81</sup>. There may be some sense<sup>82</sup> to the Darwinian<sup>83</sup> selection<sup>84</sup> process<sup>85</sup> implicit<sup>86</sup> in “benign<sup>87</sup> neglect,” but on the whole, failing to teach science survival results<sup>88</sup> in wasting a great deal of student talent<sup>89</sup> & time, & not infrequently<sup>90</sup> makes a mess of students’ lives.

Because science survival skills are rarely taught in a direct way, most young scientists need a mentor. Some will find one in graduate school, or as a postdoctoral researcher<sup>91</sup>, or perhaps as an assistant<sup>92</sup> professor<sup>93 94</sup>. Those who do not have an excellent chance of moving from graduate study to scientific retirement<sup>95</sup> without passing through a career. The unmentored

<sup>77</sup>**remainder** [n] **1.** (usually **the remainder**) [singular + singular or plural verb] the remaining people, things or time, SYNONYM: **rest**. When **the remainder** refers to a plural noun, the verb is plural.; **2.** [countable, usually singular] (*mathematics*) the numbers left after 1 number has been divided into another.

<sup>78</sup>**justify** [v] to give an explanation or excuse for something or for doing something; to show that somebody/something is right or reasonable; **the end justifies the means** [idiom] used to say that bad or unfair methods of doing something are acceptable if the result of that action is good or positive.

<sup>79</sup>**neglect** [v] **1. neglect somebody/something** to fail to take care of somebody/something; **2. neglect something** to not give enough attention to something; **3. neglect something** to ignore something because it is not important, especially in a scientific experiment, SYNONYM: **disregard**; **4. neglect to do something** to fail or forget to do something that you ought to do, SYNONYM: **omit**; [n] [uncountable] the fact of not giving enough care or attention to somebody/something; the state of not receiving enough care or attention.

<sup>80</sup>**incidentally** [adv] **1.** used to give some extra information, or to introduce a new topic; **2.** in a way that is not planned, or not of central importance, but that is concerned with something else.

<sup>81</sup>**work load** [n] the amount of work that has to be done by a particular person or organization.

<sup>82</sup>**sense** [n] **1.** [countable] the meaning that a word or phrase has; a way of understanding something; **2.** [countable] **sense of something** a feeling about something important; **3.** [singular] an understanding about something; an ability to judge something; **4.** [countable] 1 of the 5 powers (sight, hearing, smell, taste & touch) that your body uses to get information about the world around you; **make sense** [idiom] **1.** to have a meaning that can be understood; **2.** to be a sensible thing to do; **make sense of something** [idiom] to understand something that is difficult or has no clear meaning; [v] (not used in the progressive tenses) **1.** to become aware of something even though you cannot clearly see it, hear it, etc.; **2. sense something** to become aware of something by seeing it, hearing it, etc.; **3. sense something** (of a device) to discover & record or react to something.

<sup>83</sup>**Darwinian** [a] connected with the ideas of Charles Darwin.

<sup>84</sup>**selection** [n] **1.** [uncountable, countable] the process of choosing somebody/something from a group of people or things, usually according to a system; **2.** [countable] a number of people or things that have been chosen from a larger group; **3.** [countable] **selection (of something)** a collection of things from which something can be chosen, SYNONYM: **range**; **4.** [uncountable] (*biology*) (in evolution) a process in which environmental or genetic factors influence which types of living thing are more successful than others.

<sup>85</sup>**process** [n] **1.** a series of actions that are taken in order to achieve a particular result; **2.** a series of things that happen, especially ones that result in natural changes; **3.** a method of doing or making something, especially one that is used in industry; **in process** [idiom] being done; continuing; **in the process** [idiom] while doing something else, especially as a result that is not intended; **in the process of (doing) something** [idiom] in the middle of doing something that takes some time to do; [v] **1.** to treat raw material, food, etc. in order to change it, preserve it, etc.; **2. process something** to deal officially with something such as a document, application or request; **3. process something** to deal with information by performing a series of operations on it, especially using a computer.

<sup>86</sup>**implicit** [a] **1. implicit in something** forming a necessary part of something; **2.** said or written in a way that suggests something without expressing it directly, OPPOSITE: **explicit**.

<sup>87</sup>**benign** [a] **1.** (*medical*) not dangerous; not likely to cause death, OPPOSITE: **malignant**; **2.** not hurting anyone; not harmful.

<sup>88</sup>**result** [n] **1.** [countable] a thing that is caused or produced because of something else; **2.** [countable] **result (of something)** the information that you get from a piece of research or from a scientific or medical test; **3. (results)** [plural] (*business*) the financial profit or loss that a business has made during a particular period; **4. (results)** [plural] things that are achieved successfully; **5.** [countable, usually plural] (*British English*) the grade you get in an exam or in a number of exams; **6.** [countable] **result (of something)** the winner in an election; the final score in a sports event, competition, etc.; [v] [intransitive] to happen because of something else that happened 1st; **result in something** [phrasal verb] to make something happen, SYNONYM: **lead to something**.

<sup>89</sup>**talent** [n] **1.** [countable, uncountable] a natural ability to do something well; **2.** [uncountable, countable] people or a person with a natural ability to do something well.

<sup>90</sup>**infrequent** [a] not happening often, SYNONYM: **rare**. **Not infrequent** is used to mean ‘fairly frequent’, OPPOSITE: **frequent**.

<sup>91</sup>**researcher** [n] a person who does research.

<sup>92</sup>**assistant** [n] a person who helps or supports somebody, usually in their job; [a] [only before noun] (abbr., **Asst**) (often in titles) having a rank below a senior person & helping them in their work.

<sup>93</sup>**professor** [n] (abbr., **Prof.**) **1.** (*especially British English*) (*North American English full professor*) a university teacher of the highest rank; **2.** (*North American English*) a teacher at a university or college.

<sup>94</sup>**assistant professor** [n] (in the US & Canada) a teacher at a college or university who has a rank just below the rank of an associate professor.

<sup>95</sup>**retirement** [n] **1.** [uncountable, countable] the fact of stopping work because you have reached a particular age; the time when you do this; **2.** [uncountable] the period of your life after you have stopped work at a particular age; **3.** [uncountable] **retirement from something** the act of stopping a particular type of work, especially in sport or politics, etc.

can only succeed<sup>96</sup> by being considerably<sup>97</sup> more astute<sup>98</sup> than the naive<sup>99</sup>, idealistic<sup>100</sup>, & very bright<sup>101</sup> young persons who generally<sup>102</sup> choose a science major<sup>103</sup>.

These thoughts have been on my mind ever since I almost had to tell Mom & Dad that their golden<sup>104</sup> boy was not good enough to find a permanent<sup>105</sup> (or any!) job in physics, a job for which his qualifications<sup>106</sup> included<sup>107</sup> 8 years of higher education<sup>108</sup> & 4 more of postdoctoral work. The agony<sup>109</sup> of those days is not easily forgotten – the boy with the high IQ, who had skipped a grade, graduated from the Bronx High School of Science at 16 & from Columbia summa cum laude<sup>110</sup> at 20, found himself in a muddle<sup>111</sup> at 28. How do you choose a research problem? How do you give a talk? What do you do to persuade<sup>112</sup> a university or a national or industrial<sup>113</sup> lab to hire<sup>114</sup> & keep you? I hadn't a clue<sup>115</sup> until, midway<sup>116</sup> through my 2nd postdoctoral job, I had the good fortune<sup>117</sup> to spend some months collaborating<sup>118</sup> with a young professor who cared

<sup>96</sup>**succeed** [v] **1.** [intransitive] to achieve something that you have been trying to do or get; to have the result or effect that was intended. When somebody/something **only succeeds in doing something**, the opposite of what was intended is achieved.; **2.** [transitive] **succeed somebody/something** to come next after somebody/something & take their/its place or position, SYNONYM: **follow**; **3.** [intransitive] **succeed (to something)** to gain the right to a title, property, etc. when somebody dies.

<sup>97</sup>**considerably** [adv] much; a lot.

<sup>98</sup>**astute** [a] very clever & quick at seeing what to do in a particular situation, especially how to get an advantage, SYNONYM: **shrewd**.

<sup>99</sup>**naive** [a] **1.** (*disapproving*) lacking experience of life, knowledge or good judgment; **2.** (*approving*) (of people & their behavior) simple & lacking experience of life.

<sup>100</sup>**idealistic** [a] having a strong belief in perfect standards & trying to achieve them, even when this is not realistic.

<sup>101</sup>**bright** [a] (**brighter, brightest**) **1.** full of slight; shining strongly; **2.** (of a color) strong & easy to see; **3.** intelligent; quick to learn; **4.** giving reason to believe that good things will happen; likely to be successful.

<sup>102</sup>**generally** [adv] **1.** by or to most people, SYNONYM: **widely**; **2.** in most cases, SYNONYM: **usually**; **3.** without discussing the details of something.

<sup>103</sup>**major** [a] **1.** [usually before noun] large, important or serious, OPPOSITE: **minor**; **2.** [only before noun] greater or more important; main, SYNONYM: **main**; [n] (*North American English*) **1.** the main subject or course of a student at college or university; **2.** a student studying a particular subject as the main part of their course.

<sup>104</sup>**golden** [a] [usually before noun] **1.** special & wonderful; successful or likely to be successful; **2.** bright yellow in color like gold. In traditional stories, **golden** is also used to say that something is made of gold.

<sup>105</sup>**permanent** [a] lasting for a long time or for all time in the future; existing all the time, OPPOSITE: **temporary**.

<sup>106</sup>**qualification** [n] **1.** [countable] (*British English*) an exam that you have passed or a course of study that you have successfully completed; **2.** [uncountable] the fact of reaching the necessary standard for something, e.g. by passing an exam; **3.** [countable] a skill, type of experience, or quality that is needed for a particular job or activity, or to be a particular thing; **4.** [countable, uncountable] information that you add to a statement to limit the effect that it has or the way it is applied.

<sup>107</sup>**include** [v] **1.** (not used in the progressive tenses) if 1 thing includes another, it has the 2nd thing as 1 of its parts; **2.** to make somebody/something part of something, or part of a group of things, OPPOSITE: **exclude**.

<sup>108</sup>**higher education** [n] [uncountable] (abbr., **HE**) education & training at college & university, especially to degree level.

<sup>109</sup>**agony** [n] [uncountable, countable] (plural **agonies**) extreme physical or mental pain.

<sup>110</sup>**summa cum laude** [adv, a] (*from Latin*) (in the US) at the highest level of achievement that students can reach when they finish their studies at college.

<sup>111</sup>**muddle** [v] (*especially British English*) **1.** to put things in the wrong order or mix them up; **2.** **muddle somebody (up)** to confuse somebody; **3.** **muddle somebody/something (up)** | **muddle A (up) with B** to confuse 1 person or thing with another, SYNONYM: **mix up**; [n] (*especially British English*) **1.** [countable, usually singular] a state in which it is difficult to think clearly; **2.** [countable, usually singular, uncountable] **muddle (about/over something)** a situation in which there is a lack of understanding about arrangements, etc. & things are done wrong; **3.** [countable, usually singular, uncountable] a state in which things are untidy & not in order, SYNONYM: **mess**.

<sup>112</sup>**persuade** [v] **1.** to make somebody do something by giving them good reasons for doing it; **2.** to make somebody believe that something is true, SYNONYM: **convince**.

<sup>113</sup>**industrial** [a] [usually before noun] **1.** connected with industry; **2.** having many industries.

<sup>114</sup>**hire** [v] **1.** **hire somebody** (*especially North American English*) to give somebody a job; **2.** **hire somebody/something (to do something)** to employ somebody for a short time to do a particular job; **3.** **hire something** (*especially British English*) to pay money to borrow something for a short time; **hire somebody/something out** [phrasal verb] (*especially British English*) to let somebody use somebody/something for a short time, in return for payment; [n] **1.** [uncountable] (*especially British English*) the act of paying to use something for a short time; **2.** [countable] (*especially North American English*) a person who has recently been given a job by a company.

<sup>115</sup>**clue** [n] a fact or a piece of evidence that helps you discover the answer to a problem.

<sup>116</sup>**midway** [adv] **1.** in the middle of a period of time; between 2 places, SYNONYM: **halfway**; **2.** with some of the characteristics of 1 thing & some of another; [a] **1.** that is at an equal distance between 2 points; that is in the middle of a period of time; **2.** having some of the characteristics of 1 thing & some of another.

<sup>117</sup>**fortune** [n] **1.** [uncountable] chance or luck, especially in the way it affects people's lives; **2.** [countable] a large amount of money; **3.** [countable, usually plural, uncountable] the good & bad things that happen to a person, family, country, etc.

<sup>118</sup>**collaborate** [v] **1.** [intransitive] to work together with somebody in order to produce or achieve something; **2.** [intransitive] **collaborate (with somebody)** to help the enemy who has taken control of your country during a war.



whether I survived as a scientist. Although this mentoring<sup>119 120</sup> relationship<sup>121</sup> was brief<sup>122</sup>, it helped me acquire<sup>123</sup> a set of skills that graduate education did not, skills without<sup>124</sup> which my lengthy<sup>125</sup> training in physics would have been wasted.

This book is meant for those who will not be lucky<sup>126</sup> enough to find a mentor early, for those who naively suppose that getting through graduate school, doing a postdoc, etc., are enough to guarantee<sup>127</sup> a scientific career. I want you to see what stands between you & a career, to help you prepare for the inevitable<sup>128</sup> obstacles<sup>129</sup> before they overwhelm<sup>130</sup> you. In short, I hope to enable<sup>131</sup> you to use your exceptional<sup>132</sup> brainpower in the way that you & those who put you through school have dreamed about.

I begin with some brief case histories. This may help to put your own early career in better perspective<sup>133</sup>. At least I hope it will give you a feeling for how important mentoring can be.

Important or not, you are likely to wonder whether an elder who emerged into the scientific marketplace<sup>134</sup> when times were flush<sup>135</sup>, & advanced technology<sup>136</sup> looked very different from today's, can possibly offer you useful advice. Chap. 2 argues<sup>137</sup> that one can.

<sup>119</sup>**mentoring** [n] [uncountable] the practice of helping & advising a less experienced person over a period of time, especially as part of a formal programme in a company, university, etc.

<sup>120</sup>**mentorship** [n] **1.** [uncountable] the advice & help provided by a mentor to a less experienced person over a period of time, especially as part of a formal programme in a company, university, etc.; **2.** [countable] a period of time during which somebody receives advice & help from a mentor.

<sup>121</sup>**relationship** [n] **1.** [countable] the way in which 2 people, groups or countries behave towards each other or deal with each other; **2.** [countable, uncountable] the way in which 2 or more people or things are connected, SYNONYM: **relation**; **3.** [countable] a loving &/or sexual friendship between 2 people; **4.** [countable, uncountable] the way in which a person is related to somebody else in a family.

<sup>122</sup>**brief** [a] (**briefe**, **briefest**) **1.** using few words; **2.** lasting only a short time, SYNONYM: **short**, OPPOSITE: **length**; **in brief** [idiom] in a few words, without details; [n] **1.** (*British English*) the instructions that a person is given explaining what their job is & what their duties are; **2.** (*law*) a document giving the facts about a legal case; [v] to give somebody information about something so that they are prepared to deal with it.

<sup>123</sup>**acquire** [v] **1. acquire something** to learn or develop a skill, habit or quality; **2. acquire something** to obtain something by buying or being given it; **3. acquire something** to come to have a particular reputation.

<sup>124</sup>**without** [prep] **1.** not doing the action mentioned; **2.** not having, experiencing or showing something; **3.** not using or taking something.

<sup>125</sup>**lengthy** [a] (**lengthier**, **lengthiest**) very long, & often too long, in time or size.

<sup>126</sup>**lucky** [a] (**luckier**, **luckiest**) **1.** having good luck, SYNONYM: **fortunate**; **2.** being the result of good luck.

<sup>127</sup>**guarantee** [n] **1.** a firm promise that something will be done or that something will happen, SYNONYM: **assurance**; **2.** something that makes something else certain to happen; **3.** a written promise given by a company that something you buy will be replaced or repaired without payment if it goes wrong within a particular period; **4.** a written promise to pay back money that somebody else owes, or do something that somebody else promised to do, if they cannot do it themselves; [v] **1.** to promise to do or keep something; to promise something will happen or exist; **2.** to make something certain to happen; **3.** to agree to be legally responsible for something or for doing something, especially for paying back money that somebody else owes if they cannot pay it back themselves; **be guaranteed to do something** [idiom] to be certain to have a particular result.

<sup>128</sup>**inevitable** [a] **1.** that you cannot avoid or prevent, SYNONYM: **unavoidable**; **2. (the inevitable)** [n] [singular] something that is certain to happen.

<sup>129</sup>**obstacle** [n] **1.** a situation, event or fact that makes it difficult for you to do or achieve something; **2.** an object that is in your way & that makes it difficult for you to move forward.

<sup>130</sup>**overwhelm** [v] [often passive] **1.** to be so bad or so great that a person, organization or system cannot deal with it; to give too much of a thing to a person or thing; **2.** to have such a strong emotional effect on somebody that is difficult for them to resist or know how to react, SYNONYM: **overcome**; **3. overwhelm somebody** to defeat somebody completely.

<sup>131</sup>**enable** [v] **1. enable somebody to do something** to make it possible for somebody to do something, SYNONYM: **allow**; **2.** to make it possible for something to happen or exist by creating the necessary conditions, SYNONYM: **allow**.

<sup>132</sup>**exceptional** [a] **1.** very unusual; not typical; **2.** unusually good, SYNONYM: **outstanding**.

<sup>133</sup>**perspective** [n] **1.** [countable] a particular attitude towards something; a way of thinking about something, SYNONYM: **viewpoint**; **2.** [uncountable] the ability to think about problems & decisions in a reasonable way without making them seem more serious or more important than they really are; **3.** [uncountable] the art of creating an effect of depth & distance in a picture by representing people & things that are far away as being smaller than those that are nearer the front.

<sup>134</sup>**marketplace** [n] **1. (the/a marketplace)** [singular] the activity of competing with other companies to buy & sell goods or services; **2.** [countable] an open area in a town where a market is held.

<sup>135</sup>**flush** [v] **1.** [intransitive, transitive] (of a person or their face) to become red, especially because you are embarrassed, angry or hot; to make somebody's face become red; **2.** [intransitive, transitive] **flush (something)** when a toilet **flushes** or you **flush** it, water passes through it to clean it, after a handle, etc. has been pressed; **3.** [transitive] to clean something by causing water to pass through it; **4.** [transitive] **flush something + adv./prep.** to get rid of something with a sudden flow of water or other liquid; **5.** [transitive] **flush somebody/something + adv./prep.** to force a person or an animal to leave the place where they are hiding; [n] **1.** [countable, usually singular] a red color that appears on your face or body because you are embarrassed, excited or hot; **2.** [countable, usually singular] a sudden strong feeling; the hot feeling on your face or body caused by this; **3.** [singular] the act of cleaning a toilet with a sudden flow of water; **4.** [countable] (in card games) a set of cards that a player has that are all of the same suit; **(in) the 1st flush of something** [idiom] (*formal*) (at) a time when something is new, exciting & strong; [a] [not before noun] **1. (informal)** having a lot of money, usually for a short time; **2. flush with something** (of 2 surfaces) completely level with each other.

<sup>136</sup>**technology** [n] (plural **technologies**) [uncountable, countable, usually plural] equipment, machines & processes that are developed using knowledge of engineering & science; the knowledge used in developing them.

<sup>137</sup>**argue** [v] **1.** [transitive, intransitive] to give reasons why you think that something is right/wrong, true/not true, etc., especially to persuade people that you are right; **2.** [intransitive] to disagree about something; **3.** [transitive, intransitive] to show clearly that something exists or is true.

Succeeding chapters are arranged<sup>138</sup> in parallel<sup>139</sup> with a career trajectory<sup>140</sup>. Please skip<sup>141</sup> ahead<sup>142</sup> to whichever<sup>143</sup> may be relevant<sup>144</sup> to your situation<sup>145</sup>. Chap. 3 deals with choosing a thesis or a postdoctoral adviser<sup>146</sup>. My choice of thesis adviser was based on 2 criteria<sup>147</sup>: Who is the most eminent<sup>148</sup> professor in the department<sup>149</sup>? & whose students finish soonest? Was this intelligent<sup>150</sup>, or did it represent<sup>151</sup> a 1st mistake<sup>152</sup>? Chap. 4 concerns<sup>153</sup> oral presentation<sup>154</sup> of your work. However brilliant your insights<sup>155</sup>, they will be of little use if you cannot make them appear interesting<sup>156</sup> to others. If no one pays attention<sup>157</sup>, what difference<sup>158</sup> does it make if your results are clever<sup>159</sup>? There are of course Nobel

<sup>138</sup>**arrange** [v] **1.** [transitive, intransitive] to plan or organize something in advance. An **arranged marriage** is a marriage in which the parents choose the husband or wife for their child.; **2.** [transitive] **arrange something** to put something in a particular order; to make something neat or attractive.

<sup>139</sup>**parallel** [a] **1.** 2 or more lines that are parallel to each other are the same distance apart at every point; **2.** very similar; taking place at the same time; [n] **1.** [countable, uncountable] a person, a situation or an event that is very similar to another, especially one in a different place or time, SYNONYM: **equivalent**; **2.** [countable, usually plural] **parallel between A & B** a comparison between 2 things; **in parallel (with something)** [idiom] with & at the same time as something else; [v] **1.** **parallel something** to be similar to something; to happen at the same time as something; **2.** to be the same distance apart from something at every point.

<sup>140</sup>**trajectory** [n] (plural **trajectories**) (*specialist*) **1.** the curved path of something that has been fired, hit or thrown into the air; **2.** the way in which a person, an event or a process develops over a period of time, often leading to a particular result.

<sup>141</sup>**skip** [v] **1.** [transitive] **skip something** to not do something that you usually do or should do; **2.** [transitive, intransitive] to leave out something that would normally be the next thing that you would do or read.

<sup>142</sup>**ahead** [adv] **1.** further forward in time or space; in front; **2.** earlier.

<sup>143</sup>**whichever** [determiner, pronoun] **1.** used to say what feature or quality is important in deciding something; **2.** used to say that it does not matter which, as the result will be the same.

<sup>144</sup>**relevant** [a] **1.** closely connected with the subject you are discussing or the situation you are thinking about, OPPOSITE: **irrelevant**; **2.** [not usually before noun] valuable & useful to people in their lives & work.

<sup>145</sup>**situation** [n] **1.** all the circumstances & things that are happening at a particular time & in a particular place; **2.** the area or place where something is located.

<sup>146</sup>**adviser** [n] (also **advisor**) a person who gives advice, especially somebody who knows a lot about a particular subject.

<sup>147</sup>**criterion** [n] a standard or principle by which something is judged, or with the help of which a decision is made.

<sup>148</sup>**eminent** [a] [usually before noun] **1.** (of people) famous & respected, especially in a particular profession; **2.** (of good qualities) unusual; excellent.

<sup>149</sup>**department** [n] (abbr., **Dept**) a section of a large organization such as a government, business or university.

<sup>150</sup>**intelligent** [a] **1.** good at learning, understanding & thinking in a logical way about things; showing this ability; **2.** (of an animal) able to understand & learn things; **3.** (*computing*) (of a computer or program) able to use data it has stored in new situations & to react to changes.

<sup>151</sup>**represent** [v] **1.** + **noun linking verb** (not used in the progressive tenses) to be something; to be equal to something, SYNONYM: **constitute**; **2.** (not used in the progressive tenses) **represent something** to be a symbol or sign of something, SYNONYM: **symbolize**; **3.** [no passive] **represent something** to be typical of something; **4.** to show or describe somebody/something in a particular way, SYNONYM: **present**; **5.** (not used in the progressive tenses) **represent somebody/something** to include a particular type or number of people or things; **6.** **be represented** + **adv./prep.** to be present to a particular degree; **7.** to act or speak for somebody/something; to attend or take part in an event on behalf of somebody; **8.** **represent somebody/something** to show somebody/something, especially in a picture or diagram, SYNONYM: **depict**; **9.** **represent something** to say or suggest something that you want somebody to believe or pay attention to.

<sup>152</sup>**mistake** [n] **1.** an action or opinion that is not correct, or that produces a result that is not wanted. **Make no mistake** is sometimes used in less formal writing to emphasize that what you are saying is correct. This use is best avoided in more formal writing.; **2.** a word, figure, fact, etc. that is not correct, SYNONYM: **error**; **by mistake** [idiom] by accident; without intending to. **By mistake** is very common in general English, & is also used in academic English. However, in academic English, the more formal **accidentally** & **unintentionally** are more common.; [v] **mistake something/somebody for something/somebody** [often passive] to think wrongly that something/somebody else.

<sup>153</sup>**concern** [v] **1.** [often passive] to affect somebody/something; to involve somebody/something; **2.** to be about something; **3.** to take an interest in something; to cause somebody to take an interest in something; **4.** [usually passive] to make somebody anxious; **5.** (**be concerned to do something**) to think it is important to do something; **as/so far as somebody/something is concerned**; **as/so far as somebody/something goes** [idiom] used to give facts or an opinion about a particular aspect of something; [n] **1.** [countable, uncountable] a feeling of being anxious, especially a feeling that is shared by many people; **2.** [countable] something that is important to a person, an organization, etc.; **3.** [singular, uncountable] **concern (for something/somebody)** a desire to protect & help somebody/something; **4.** [countable, usually singular] **concern (of something/somebody)** something that is your responsibility or that you have a right to know about.

<sup>154</sup>**presentation** [n] **1.** [countable, uncountable] the act of showing or offering information or ideas for other people to consider; an occasion when this happens; **2.** [countable, uncountable] **presentation of something** the way that somebody/something is shown or described; **3.** [uncountable] the act of giving or showing something to somebody in a formal situation; **4.** [countable, uncountable] (*medical*) the way that a condition or patient is or appears; the occasion when a condition or patient is seen or examined.

<sup>155</sup>**insight** [n] **1.** [countable, uncountable] an understanding of a particular situation or thing; **2.** [uncountable] the ability to see & understand the truth about people or situations.

<sup>156</sup>**interesting** [a] attracting your attention because it is special, exciting or unusual.

<sup>157</sup>**attention** [n] **1.** [uncountable] the act of listening to, looking at or thinking about something/somebody carefully; interest that people show in somebody/something; **2.** [uncountable] special care, action or treatment; **3.** [countable, usually plural] things done to try to please somebody or to show an interest in them.

<sup>158</sup>**difference** [n] **1.** [countable, uncountable] the way in which 2 people or things are not like each other; the state of being different, OPPOSITE: **similarity**; **2.** [uncountable, countable, usually singular] the amount by which something is greater or smaller than something else; **3.** [countable] a disagreement between people, SYNONYM: **disagreement**.

<sup>159</sup>**clever** [a] (**cleverer, cleverest**) (You can also use **more clever** & **most clever**) **1.** (*especially British English*) quick at learning & understanding things, SYNONYM: **intelligent**; **2.** **clever (at something/doing something)** (*especially British English*) skilful; **3.** showing intelligence or skill, e.g. in the design of an object, in an idea or somebody's actions.

prize<sup>160</sup> – winners<sup>161</sup> whose orations<sup>162</sup> are Delphic<sup>163</sup>, whose visuals<sup>164</sup> look as though they were put together during a particularly<sup>165</sup> turbulent<sup>166</sup> flight<sup>167</sup>, & so on. But you are not 1 of them yet, & if that is how your talks are prepared, you never will be either. There is more to Chap. 4, though, than advice on preparing appealing<sup>168</sup> slides. It contains a range of important ideas on making your oral presentations effective.

In Chap. 5, you will find a discussion<sup>169</sup> of paper writing. Through your scholarly<sup>170</sup> articles, you can make yourself known nationally<sup>171</sup> & internationally<sup>172</sup>. This means that your reputation<sup>173</sup> in science does not just depend<sup>174</sup> on what your boss<sup>175</sup> says about you but also on documentation<sup>176</sup> that is readily<sup>177</sup> available<sup>178</sup> on the Internet<sup>179</sup>. You should therefore<sup>180</sup> view<sup>181</sup> publishing<sup>182</sup> as a means to attaining<sup>183</sup> job security<sup>184 185</sup> & take the task<sup>186</sup> of writing compelling<sup>187</sup> journal articles very seriously<sup>188</sup>.

<sup>160</sup>**Nobel Prize** [n] 1 of 6 international prizes given each year for excellent work in physics, chemistry, medicine, literature, economics & work towards world peace.

<sup>161</sup>**winner** [n] a person, team, animal, etc. that wins something.

<sup>162</sup>**oration** [n] (*formal*) a formal speech made on a public occasion, especially as part of a ceremony.

<sup>163</sup>**Delphic** [a] **1.** relating to the ancient Greek oracle at Delphi (= the place where people went to ask the gods for advice or information about the future); **2.** (*often delphic*) (*formal*) with a meaning that is deliberately hidden or difficult to understand.

<sup>164</sup>**visual** [n] a picture, piece of film, map, etc. used to make something easier to understand or more interesting.

<sup>165</sup>**particularly** [adv] especially; more than usual or more than others.

<sup>166</sup>**turbulent** [a] [usually before noun] **1.** (of air or water) changing direction suddenly & violently; **2.** in which there is a lot of sudden change; confusion, disagreement & sometimes violence.

<sup>167</sup>**flight** [n] **1.** [uncountable] the act of flying; **2.** [countable] a journey made by air, especially in a plane; a plane making a particular journey; **3.** [uncountable, singular] the act of running away from a dangerous or difficult situation; **4.** [countable] **flight (of stairs/steps)** a series steps between 2 floors or levels.

<sup>168</sup>**appealing** [a] attractive or interesting.

<sup>169</sup>**discussion** [n] [countable, uncountable] **1.** a speech or a piece of writing that discusses many different aspects of a subject; **2.** a conversation about somebody/something; the process of discussing somebody/something. If something is **under discussion**, it is being talked about so that a decision can be made.

<sup>170</sup>**scholarly** [a] **1.** involving or connected with serious academic study, SYNONYM: **academic**; **2.** having or showing a lot of knowledge as a result of serious academic study.

<sup>171</sup>**nationally** [adv] connected with a country as a whole; connected with a particular country.

<sup>172</sup>**internationally** [adv] in, by or between 2 or more countries.

<sup>173</sup>**reputation** [n] the opinion that people have about what somebody/something is like, based on what has happened in the past.

<sup>174</sup>**depend** [v] **depend on/upon something** (not used in the progressive tenses) to be affected or decided by something; **depend on/upon somebody/something (for something)** (not used in the progressive tenses) to need money or help from somebody/something else for a particular purpose.

<sup>175</sup>**boss** [n] **1.** a person who is in charge of other people at work & tells them what to do; **2.** (*informal*) a person who is in charge of a large organization; **show somebody who's boss** [idiom] to make it clear to somebody that you have more power & authority than they have; [v] **boss somebody (about/around)** to tell somebody what to do in an aggressive &/or annoying way; [a] (*especially North American English, slang*) very good.

<sup>176</sup>**documentation** [n] [uncountable] **1.** the documents that are required for something, or that give evidence or proof of something, or information about it; **2. documentation (of something)** the act of recording something in a document.

<sup>177</sup>**readily** [adv] **1.** quickly & without difficulty, SYNONYM: **freely**; **2.** in a way that shows that you do not object to something, SYNONYM: **willingly**.

<sup>178</sup>**available** [a] **1.** (of things) that you can use or obtain, OPPOSITE: **unavailable**; **2. available (for something)** (of a person) free or willing to do something, OPPOSITE: **unavailable**.

<sup>179</sup>**Internet** [n] (also **internet**) (usually **the Internet**) [singular] an international computer network which is used for finding & sharing information & for email.

<sup>180</sup>**therefore** [adv] used to introduce the logical result of something that has just been mentioned.

<sup>181</sup>**view** [n] **1.** [countable] a personal opinion about something; an attitude towards something; **2.** [singular] a way of understanding or thinking about something; **3.** [uncountable, singular] used when you are talking about whether somebody/something can be seen from a particular place; **4.** [countable] what you can see from a particular place, especially beautiful countryside; [v] **1. view somebody/something + adv./prep.** to think about somebody/something in a particular way; **2.** to look at something; **3. view something** to watch television, a film, etc.

<sup>182</sup>**publishing** [n] [uncountable] the profession, business or activity of preparing books, articles, etc. & selling them or making them available to the public.

<sup>183</sup>**attain** [v] **1. attain something** to succeed in achieving something, usually after a lot of effort; **2. attain something** to reach a particular age, size or level.

<sup>184</sup>**security** [n] (plural **securities**) **1.** [uncountable] the activities involved in protecting a country, building or person against attack or danger; **2.** [uncountable] protection against something bad that might happen in the future; the degree to which something is safe & protected; **3. (securities)** [plural] (*finance*) documents that can be bought & sold giving somebody the rights no money earned from a particular business or venture; **4.** [uncountable] the fact of agreeing that a valuable item, such as a house, will be given to somebody if you are unable to pay back the money that you have borrowed from them; **5.** [uncountable] the state of feeling happy & safe from danger or worry.

<sup>185</sup>**job security** [n] [uncountable] the state of having a job that is secure.

<sup>186</sup>**task** [n] a piece of work that has to be done; **take somebody to task (for something/for doing something)** [idiom] to criticize somebody for something.

<sup>187</sup>**compelling** [a] **1.** that makes you think it is true or valid; **2.** making you pay attention through being so interesting & exciting; **3.** that cannot be resisted.

<sup>188</sup>**seriously** [adv] **1.** to a degree that is important & worrying; **2.** carefully & sincerely; **take somebody/something seriously** [idiom] to think that somebody/something is important & deserves attention & respect.

Chap. 6 is devoted<sup>189</sup> to career choices, mainly<sup>190</sup> the merits<sup>191</sup> & defects<sup>192</sup> of positions in academia & in government or industrial labs. The focus<sup>193</sup> is on being reflective<sup>194</sup> & rational<sup>195</sup> rather than naive or romantic<sup>196</sup> about key<sup>197</sup> decisions<sup>198</sup> in your scientific life. In Chap. 7, I discuss job interviews. There is more to an interview than wearing your Sunday best & having a firm<sup>199</sup> handshake<sup>200</sup>. Doing your homework<sup>201</sup> & persuading your potential<sup>202</sup> employers<sup>203</sup> that you have a sense

<sup>189</sup>**devote** [v] **devote yourself to somebody/something** to give most of your time, energy or attention to somebody/something, SYNONYM: **dedicate**; **devote something to something** to give an amount of time, attention or resources to something.

<sup>190</sup>**mainly** [adv] **1.** more than anything else, SYNONYM: **chiefly, primarily**; **2.** in most cases; used to talk about the largest part of a group of people or things; **3.** concerning the greater part of something.

<sup>191</sup>**merit** [n] **1.** [countable, usually plural] a good feature that deserves praise, reward or admiration, SYNONYM: **strength**; **2.** [uncountable] the quality of being good & of deserving praise, reward or admiration, SYNONYM: **worth**; [v] (not used in the progressive tenses) **merit something** to do something to deserve praise or attention, SYNONYM: **deserve**.

<sup>192</sup>**defect** [n] something that is wrong with or missing from somebody/something; [v] **1.** [intransitive] **defect (from something) (to something)** to leave a political party, country, etc. to join another that is considered to be an enemy; **2.** [intransitive] **defect (from something) (to something)** to leave a group, an arrangement or a relationship & join or start another.

<sup>193</sup>**focus** [v] **1.** [intransitive, transitive] to give attention or effort to a particular thing (or to just a few things), rather than to many things. Although **focus** is most commonly used with **on** on this meaning, it is sometimes used without **on** or **upon**; **2.** [intransitive, transitive] (of a person or their eyes, or a camera, etc.) to adjust or be adjusted, so that things can be seen clearly; **3.** [transitive] (*physics*) to condense a beam of light or other energy; [n] (plural **focuses, foci**) **1.** [uncountable, countable, usually singular] attention or effort that is given to a particular thing (or to just a few things), rather than to lots of things. **Shift & change** are used as a verb & noun with **focus**; **2.** [countable, usually singular] the main thing that people are interested in or are working on; **3.** [uncountable, countable, usually singular] the quality or state of being seen with clear edges; a device (e.g., on a microscope) that allows this; **4.** [countable] (*physics*) = **focal point**; **5.** [countable] (*earth sciences*) the point below the earth's surface where an earthquake starts; **6.** [countable] **focus (for something)** (*medical*) the part of somebody's body in which a disease starts or is most developed; **bring something into focus** [idiom] to make something very clear, SYNONYM: **highlight**; **come into focus** [idiom] to become very clear.

<sup>194</sup>**reflective** [a] **1.** thinking carefully about things, especially about your work or studies; **2.** **reflective of something** typical of a particular situation or thing; showing the state or nature of something; **3.** reflective surfaces send back light or heat.

<sup>195</sup>**rational** [a] **1.** (of behavior or ideas) based on reason rather than emotions, OPPOSITE: **irrational**; **2.** (of a person) able to think clearly & make decisions based on reason rather than emotions, SYNONYM: **reasonable**, OPPOSITE: **irrational**.

<sup>196</sup>**romantic** [a] **1.** involving love between 2 people who are sexually attracted to each other; **2.** connected with love, especially in a way that is too obvious or perfect; **3.** having an attitude to life in which imagination & the emotions are especially important; not looking at situations in a realistic way; **4.** (**Romantic**) [usually before noun] used to describe literature, music or art, especially of the 19th century, that is concerned with strong feelings, imagination & a return to nature, rather than reason & order.

<sup>197</sup>**key** [a] most important; essential, SYNONYM: **critical, vital**; [n] **1.** a specially shaped piece of metal used for locking a door, starting a car, etc.; **2.** [usually singular] a thing that provides a means of achieving or understanding something, SYNONYM: **secret**; **3.** any of the buttons that you press to operate a computer or telephone; **4.** a word or system for solving a code; **5.** a set of answers to exercises or problems; **6.** a list explaining the symbols used in a map, plan, table, etc.

<sup>198</sup>**decision** [n] **1.** [countable] a choice or judgment that you make after thinking & talking about what is the best thing to do; **2.** [uncountable] the process of deciding something.

<sup>199</sup>**firm** [n] a business or company, especially one involving a partnership of 2 or more people; [a] (**firmer, firmest**) **1.** fairly hard; not easy to press into a different shape, OPPOSITE: **soft**; **2.** [usually before noun] not likely to change; that you can rely on; **3.** strongly fixed in place, OPPOSITE: **unstable**; **4.** showing that you are strong & in control of a situation; **5.** (of somebody's voice or hand movements) strong & steady; **stand fast/firm** [idiom] **1.** to refuse to change your opinions; **2.** to refuse to move back.

<sup>200</sup>**handshake** [n] an act of shaking somebody's hand with your own, used especially to say hello or goodbye or when you have made an agreement.

<sup>201</sup>**homework** [uncountable] **1.** work that is given by teachers for students to do at home; **2.** (*informal*) work that somebody does to prepare for something.

<sup>202</sup>**potential** [a] [only before noun] that can develop into something or be developed in the future, SYNONYM: **possible**; [n] **1.** [uncountable] the possibility of something happening or being developed or used; **2.** [uncountable] qualities that exist & can be developed; **3.** [uncountable, countable] (*physics*) the difference in voltage between 2 points in an electric field or circuit.

<sup>203</sup>**employer** [n] a person or company that pays people to work for them.



of direction<sup>204</sup> are the most important issues<sup>205</sup>. Incidentally<sup>206</sup>, this is not a matter<sup>207</sup> of deception<sup>208</sup> – knowing who your colleagues<sup>209</sup> will be & developing an idea of what you want to know, scientifically<sup>210</sup>, are keys to having a productive<sup>211</sup> career. There are also a few choice words in this chapter about negotiations<sup>212</sup>, once you do get an offer<sup>213</sup>. Negotiating<sup>214</sup> for what you will need when your leverage<sup>215</sup> is maximal<sup>216</sup> can make a large difference to your happiness & to your success<sup>217</sup>.

In Chap. 8, I discuss what – to many – is the bane of scientific life, namely, getting money<sup>218</sup>. This used to be the exclusive<sup>219</sup> headache<sup>220</sup> of those in academia, but nowadays<sup>221</sup> it is also a significant<sup>222</sup> part of the lives of government & industrial scientists. I suggest<sup>223</sup> that you view the preparation<sup>224</sup> of a proposal<sup>225</sup> as an important scientific exercise<sup>226</sup>.

<sup>204</sup>**direction** [n] **1.** [countable, uncountable] the general position that somebody/something moves or points towards; **2.** [countable, uncountable] the general way in which somebody/something develops; **3.** [countable] the general position a person or thing comes or develops from; **4.** [uncountable] a purpose; an aim; **5.** (**directions**) [plural] instructions on how to do something or how to teach a place; **6.** [uncountable] the art of managing or guiding somebody/something; **pull in different/opposite directions** [idiom] to have different aims that cannot be achieved together without causing problems.

<sup>205</sup>**issue** [n] **1.** [countable] an important topic that people are discussing or arguing about; **2.** [countable] (often **issues** [plural]) a problem, concern or difficulty; **3.** [countable] 1 of a regular series of magazines or newspapers; **4.** [countable, uncountable] something that is supplied or made available for people to buy or use; the act of supplying or making available things for people to buy or use; **5.** [uncountable] (*law*) children of your own; [v] **1.** to make something known formally; to make something available publicly; **2.** [often passive] to give something to somebody, especially officially; **3.** **issue something** to start a legal process against somebody, especially by means of an official document; **4.** **issue something** to produce new stamps, coins, shares, etc. for sale to the public; **issue from something** (*formal*) [phrasal verb] to come out of something.

<sup>206</sup>**incidentally** [adv] **1.** used to give some extra information, or to introduce a new topic; **2.** in a way that is not planned, or not of central importance, but that is connected with something else.

<sup>207</sup>**matter** [n] **1.** [uncountable] a substance of a particular sort; **2.** [uncountable] physical substance in general that everything in the world consists of; **3.** [countable] a subject or situation that you must consider or deal with; **4.** (**matters**) [plural] the present situation; the situation that you are talking about, SYNONYM: **thing**; **5.** [singular] **matter of something** a situation that involves something or depends on something, SYNONYM: **question**; **6.** [uncountable] written or printed material; [v] [intransitive, transitive] (not used in the progressive tenses) to be important or have an important effect on somebody/something.

<sup>208</sup>**deception** [n] **1.** [uncountable] the act of deliberately making somebody believe something that is not true, SYNONYM: **deceit**; **2.** [countable] something that you say or do that is intended to make somebody believe something that is not true.

<sup>209</sup>**colleague** [n] a person that you work with, especially in a profession or business.

<sup>210</sup>**scientifically** [adv] **1.** in a way that is connected with science; **2.** in a careful & organized way.

<sup>211</sup>**productive** [a] **1.** making goods or growing crops, especially in large quantities, OPPOSITE: **unproductive**; **2.** doing or achieving a lot, SYNONYM: **fruitful**; **3.** **productive of something** resulting in something or causing something; **4.** (*linguistics*) connected with producing language or information that you have learned, in speech or writing; **5.** (*medical*) (of a cough) that produces mucus.

<sup>212</sup>**negotiation** [n] [countable, usually plural, uncountable] formal discussion between people who are trying to reach an agreement.

<sup>213</sup>**offer** [v] **1.** [transitive] to give or provide something; **2.** [transitive] to say that you are willing to give something to somebody or to do something for somebody; **have something to offer** [idiom] to have something available that somebody wants; [n] **1.** an act of saying that you are willing to do something for somebody or give something to somebody; **2.** **offer (of something)** an amount of money that somebody is willing to pay for something; **3.** a reduction in the normal price of something, usually for a short period of time; **on offer** [idiom] that can be bought, used, etc.

<sup>214</sup>**negotiate** [v] **1.** [intransitive] to try to reach an agreement by formal discussion; **2.** [transitive] to arrange or agree something by formal discussion; **3.** [transitive] **negotiate something (+ adv./prep.)** to successfully get over or past a difficult part on a path or route; **4.** [transitive] **negotiate something (+ adv./prep.)** to successfully solve a problem that is preventing you from achieving something.

<sup>215</sup>**leverage** [n] **1.** the ability to influence what people do; **2.** (*finance*) the relationship between the amount of money that a company owes & the values of the assets used as security for that debt; [v] **leverage something (business)** to get as much advantage or profit as possible from something that you have.

<sup>216</sup>**maximal** [a] [usually before noun] (*specialist*) as great or as large as possible.

<sup>217</sup>**success** [n] **1.** [uncountable] the fact that something/somebody achieves a good result, OPPOSITE: **failure**; **2.** [uncountable] **success (as something)** the fact that somebody achieves a high position in a particular activity; the fact of becoming rich or famous; **3.** [countable] a thing or person that has achieved a good result & been successful, OPPOSITE: **failure**.

<sup>218</sup>**bane** [n] [singular] **the bane of somebody/something** something that causes trouble & makes people unhappy.

<sup>219</sup>**exclusive** [a] **1.** limited to 1 particular person, group or area; only given to 1 particular person, group or area; **2.** not including or allowing other things; complete; **3.** (of a group of society) not very willing to allow new people to become members, especially if they are from a lower social class, OPPOSITE: **inclusive**; **4.** that cannot exist or be a true statement at the same time as something else; **5.** of a high quality & expensive & therefore not often bought or used by most people; **6.** **exclusive of something** not including.

<sup>220</sup>**headache** [n] a continuous pain in the head.

<sup>221</sup>**nowadays** [adv] at the present time, in contrast with the past.

<sup>222</sup>**significant** [a] **1.** large or important enough to have an effect or to be noticed, OPPOSITE: **insignificant**; **2.** having a particular meaning; **3.** (*statistics*) having statistical significance, OPPOSITE: **insignificant**.

<sup>223</sup>**suggest** [v] **1.** to put forward an idea or a plan for other people to consider, SYNONYM: **propose**; **2.** to put an idea into somebody's mind; to make somebody think that something is true, SYNONYM: **indicate**; **3.** to recommend somebody/something for a particular job or purpose, SYNONYM: **recommend**. You cannot 'suggest somebody something'; **4.** to state or express something in an indirect way, SYNONYM: **imply**; **5.** **suggest itself (to somebody)** (of an idea) to come into somebody's mind; (**this**) **is not to suggest that ...** [idiom] used to give added information that corrects or changes slightly something you have just said.

<sup>224</sup>**preparation** [n] **1.** [uncountable] the act or process of making something/somebody ready or of getting ready for something; **2.** [countable, usually plural] things that you do to get ready for something or to make something ready; **3.** [countable] a substance that has been specially prepared for use as a medicine, cosmetic, etc.

<sup>225</sup>**proposal** [n] **1.** a formal suggestion or plan; **2.** **proposal (that ...)** an explanation suggested for people to consider.

<sup>226</sup>**exercise** [n] **1.** [uncountable] physical or mental activity that you do to stay healthy or become stronger; **2.** [countable] a set of movements or

Coming to see & being able to articulate<sup>227</sup> how your work fits into “the big<sup>228</sup> picture<sup>229</sup>” is essential<sup>230</sup> not only to winning financial<sup>231</sup> support<sup>232</sup> but also to being a 1st-class<sup>233 234</sup> researcher. Learning to distinguish<sup>235</sup> extravagant<sup>236</sup> “pie in the sky” from promises<sup>237</sup> that you have a chance<sup>238</sup> of fulfilling<sup>239</sup> is also very valuable<sup>240</sup>.

The most difficult<sup>241</sup> problem in being a scientist is selecting what to work on, & it is even more difficult when you are

activities that you do to stay healthy or develop a skill; **3.** [countable] a set of questions in a book that tests your knowledge or practices a skill; **4.** [uncountable] **exercise of something** the use of power, a skill, a quality or a right to make something happen; **5.** [countable] an activity that is designed to achieve a particular result; **6.** [countable, usually plural] a set of activities for training soldiers; [v] **1.** [transitive] **exercise something** to use your power, rights or personal qualities in order to achieve something; **2.** [intransitive] to do sports or other physical activities in order to stay healthy or become stronger; **3.** [transitive] **exercise something** to give a part of the body the movement & activity it needs to keep strong & healthy.

<sup>227</sup>**articulate** [v] **1.** [transitive] to express or explain your thoughts or feelings clearly in words; **2.** [transitive] **articulate (something)** to speak or pronounce something in a clear way; **3.** [intransitive, transitive] (*specialist*) to be joined to something else by a joint, so that movement is possible; to join something in this way; **4.** [intransitive] **articulate (with something)** (*formal*) to be connected with something so that together the 2 parts form a whole; [a] **1.** (of a person) good at expressing ideas or feelings clearly in words; **2.** (of speech or writing) clearly pronounced or expressed.

<sup>228</sup>**big** [a] (**bigger, biggest**) **1.** (*rather informal*) large in degree, size, amount, etc.; **2.** [only before noun] (*informal*) important; serious; **the big picture** [idiom] something considered as a whole.

<sup>229</sup>**picture** [n] **1.** a painting or drawing, etc. that shows a scene, person or thing; **2.** a photograph; **3.** **picture (of somebody/something)** an image on a television screen; **4.** **picture (of somebody/something)** a description that gives you idea in your mind of what somebody/something is like; **5.** (usually **the picture**) [singular] the general situation concerning somebody/something; **the big picture** [idiom] something considered as a whole; [v] **1.** to imagine somebody/something; to create an image of somebody/something in your mind; **2.** [usually passive] to describe to present somebody/something in a particular way, SYNONYM: **portray**; **3.** [usually passive] to show somebody/something in a photograph or picture.

<sup>230</sup>**essential** [a] **1.** completely necessary; extremely important in a particular situation or for a particular activity, SYNONYM: **vital**; **2.** [only before noun] connected with the most important aspect or basic nature of somebody/something, SYNONYM: **fundamental**; **3.** (of an amino acid or fatty acid) required for normal growth but not produced in the body, & therefore necessary in the diet; [n] [usually plural] **1.** something that is needed in a particular situation or in order to do a particular thing; **2.** **essential (of something)** an important basic fact or piece of knowledge about a subject.

<sup>231</sup>**financial** [a] [usually before noun] connected with money & finance.

<sup>232</sup>**support** [v] **1.** **support something** to help to show that something is true or correct, SYNONYM: **corroborate**; **2.** to agree with & encourage an idea, plan, person, group, etc., SYNONYM: **back**; **3.** to help or encourage somebody to do something; **4.** **support somebody/something/yourself** to provide money so that somebody can buy what they need; **5.** **support something** to help or encourage something to be successful by giving it money, SYNONYM: **sponsor**; **6.** **support something** to produce enough food & water for somebody/something; to provide a good environment for somebody/something to live in; **7.** **support somebody/something** to hold somebody/something in position; to prevent somebody/something from falling; [n] **1.** [uncountable, countable] approval, encouragement, help or comfort that is given to somebody/something; a person or thing that provides this; **2.** [uncountable] money or items that are provided to a person or organization that needs them; **3.** [uncountable] evidence that helps to show that something is true or correct; **4.** [uncountable] the act of holding something firmly in position or preventing it from falling; **5.** [countable] a thing that holds something in position or prevents it from falling.

<sup>233</sup>**first-class** [a] **1.** [usually before noun] in the best group; of the highest standard, SYNONYM: **excellent**; **2.** [only before noun] connected with the best & most expensive way of traveling on a train, plane or ship; **3.** [only before noun] (in the UK) connected with letters, packages, etc. that are delivered most quickly, or that cost more to send; **4.** [only before noun] used to describe a university degree of the highest class from a British university.

<sup>234</sup>**first class** [n] [uncountable] **1.** the best & most expensive seats or accommodation on a train, plane or ship; **2.** (in the UK) the class of mail that is delivered most quickly; **3.** (in the US) the class of mail that is used for letters; **4.** the highest standard of degree given by a British university.

<sup>235</sup>**distinguish** [v] **1.** [intransitive, transitive] to recognize or show the difference between 2 people or things, SYNONYM: **differentiate**; **2.** [transitive] (not used in the progressive tenses) to be a characteristic that makes 2 people, animals or things different, SYNONYM: **differentiate**; **3.** [transitive] **distinguish A (from B)** to make something different or seem different from other similar things, SYNONYM: **differentiate**; **4.** [transitive] to do something so well that people notice & admire you; **5.** [transitive] (not used in the progressive tenses) **distinguish something** to be able to see or hear something, SYNONYM: **make somebody/something out**.

<sup>236</sup>**extravagant** [a] **1.** spending a lot more money or using a lot more of something than you can afford or than is necessary; **2.** costing a lot more money than you can afford or is necessary; **3.** (of ideas, speech or behavior) very extreme or impressive but not reasonable or practical, SYNONYM: **exaggerated**.

<sup>237</sup>**promise** [n] **1.** [countable] a statement in which you say that you will definitely do something, or that something will definitely happen; **2.** [uncountable] the quality of being likely to be excellent or successful, SYNONYM: **potential**; **3.** [uncountable, singular] a sign or a reason for hope that something may happen, especially something good; [v] **1.** [intransitive, transitive] to tell somebody that you will definitely do something, or that something will definitely happen; **2.** [transitive] to make something seem likely to happen; to show signs of something.

<sup>238</sup>**chance** [n] **1.** [countable, uncountable] a possibility of something happening, especially something that you want; **2.** [countable] a suitable time or situation when you have the opportunity to do something; **3.** [countable, usually plural] used to refer to the opportunities that somebody has in their life; **4.** [uncountable] the way that some things happen without any cause that you can see or understand.

<sup>239</sup>**fulfil** [v] (*British English*) (*North American English fulfill*) **1.** **fulfil something** to do or have what is required or necessary; **2.** **fulfil something** to have a particular role or purpose; **3.** **fulfil something** to do or achieve what was hoped for or expected.

<sup>240</sup>**valuable** [a] **1.** very useful or important; **2.** worth a lot of money, OPPOSITE: **worthless**.

<sup>241</sup>**difficult** [a] **1.** not easy; needing effort or skill to do or to understand, SYNONYM: **hard**, OPPOSITE: **easy**; **2.** [only before noun] full of problems; causing a lot of trouble, SYNONYM: **hard**; **3.** (of people) not easy to please; not helpful, SYNONYM: **awkward, demanding; make life difficult**



just launching<sup>242</sup> your career. Therefore, in Chap. 9, I venture<sup>243</sup> a few comments<sup>244</sup> on establishing a research program. Jumping into the hottest research area may not be a very good idea, nor is taking on a project<sup>245</sup> that you have no realistic<sup>246</sup> hope<sup>247</sup> of completing before your short-term<sup>248</sup> employment comes to an end. The main idea is to establish a program that simultaneously<sup>249</sup> maximizes<sup>250</sup> your chances of continuing employment & of scientific achievement<sup>251</sup>. The focus is on strategic<sup>252</sup> thinking<sup>253</sup>.

As this book is written, economic<sup>254</sup> times are tough<sup>255</sup> worldwide<sup>256</sup>, & funding<sup>257</sup> for scientific research is contracting<sup>258</sup>.

(for somebody/something) [idiom] to cause problems for somebody/something.

<sup>242</sup>**launch** [v] **1. launch something** to start an activity, especially an organized one; **2. launch something** to make a product available to the public for the 1st time; **3. launch something** to send something such as a satellite, weapon, etc. into space, into the sky or through water; **4. launch something** to put a ship or boat into the water, especially one that has just been built; **launch into something** [phrasal verb] to begin something in an enthusiastic way, especially something that will take a long time; [n] the action of launching something; an event at which something is launched.

<sup>243</sup>**venture** [n] **1.** a business project or activity, especially one that involves taking risks, SYNONYM: **undertaking**; [v] **1.** [intransitive] + **adv./prep.** to go somewhere or do something even though it involves risks; **2.** [transitive, intransitive] (*formal*) to say or do something in a careful way, especially because it might upset or offend somebody.

<sup>244</sup>**comment** [n] [countable, uncountable] something that you say or write that gives an opinion on or explains; [v] [intransitive, transitive] to express an opinion about something.

<sup>245</sup>**project** [n] **1.** a planned piece of work that is designed to find information about something, to produce something new or to improve something; **2.** a piece of research work done by a school or college student; **3. project (of something/of doing something)** a set of aims, ideas or activities that somebody is interested in or wants to bring to people's attention; [v] **1.** [transitive, usually passive] to estimate what the size, cost or amount of something will be in the future, based on what is happening now, SYNONYM: **forecast**; **2.** [transitive, usually passive] **be projected (for something)** to plan an activity, a project, etc. for a time in the future; **3.** [transitive] to present somebody/something/yourself to other people in a particular way, especially one that gives a good impression; **4.** [intransitive] + **adv./prep.** to stick out beyond an edge or surface; **5.** [transitive] **project something/somebody (+ adv./prep.)** to throw something or make something move forward or away; **6.** [transitive] **project something (on/onto something)** to make light, an image, etc. fall onto a flat surface or screen; **project something onto somebody** [phrasal verb] to imagine that other people have the same feelings, problems, etc. as you, especially when this is not true.

<sup>246</sup>**realistic** [a] **1.** sensible & appropriate; possible to achieve, SYNONYM: **feasible**, **viable**, OPPOSITE: **unrealistic**; **2.** accepting in a sensible way what it is actually possible to do or achieve in a particular situation, OPPOSITE: **unrealistic**; **3.** representing things as they are in real life, OPPOSITE: **unrealistic**.

<sup>247</sup>**hope** [v] [intransitive, transitive] to want something to happen & think that it is possible. **Hope** can be used in the passive in the form **it is hoped that** ... In other passive sentences, **hope** must always be followed by **for**; [n] **1.** [uncountable, countable] a belief that something you want will happen; **2.** [countable] something that you wish for; **3.** [countable, usually singular] a person, a thing or a situation that will help you get what you want; **hold out (the) hope (of something/that ...)** [idiom] to hope & expect that something will happen.

<sup>248</sup>**short-term** [a] [usually before noun] lasting a short time; designed only for a short period of time in the future. **Short-term memory** is the ability to remember things that happened a short time ago.

<sup>249</sup>**simultaneously** [adv] at the same time as something else.

<sup>250</sup>**maximize** [v] (*British English also maximise*) **1. maximize something** to make something as large or as great as possible, OPPOSITE: **minimize**; **2. maximize something** to make the best use of something.

<sup>251</sup>**achievement** [n] **1.** [countable] a thing that somebody has done successfully, especially using their own effort & skills; **2.** [uncountable] the fact or process of achieving something; **3.** [uncountable] a child's or student's progress in a course of learning, especially as measured by standard tests.

<sup>252</sup>**strategic** [a] [usually before noun] **1.** done as part of a plan that is meant to achieve a particular purpose or to gain an advantage; **2.** connected with gaining an advantage in a war or other military situation; **3.** (of weapons, especially nuclear weapons) intended to be fired at an enemy's country rather than used in a battle.

<sup>253</sup>**thinking** [n] [uncountable] **1.** the process of thinking about something; **2.** ideas or opinions about something.

<sup>254</sup>**economic** [a] **1.** [only before noun] connected with the trade, industry & development of wealth of a country, an area or a society; **2.** producing enough profit to continue; not consisting much money, SYNONYM: **profitable**.

<sup>255</sup>**tough** [a] (**tougher**, **toughest**) **1.** (of a thing) not easily damaged; strong; **2.** (*rather informal*) having or causing problems, SYNONYM: **difficult**; **3.** (*rather informal*) having or causing problems, SYNONYM: **difficult**; **3.** (*rather informal*) demanding that laws be obeyed, & not accepting any reasons for not obeying them, OPPOSITE: **soft**; **4.** (*rather informal*) (of a person) strong enough to deal successfully with difficult conditions or situations. **Tough** can sometimes suggest that somebody may be violent. The more formal word **resilient** does not suggest this.

<sup>256</sup>**worldwide** [a] [usually before noun] affecting all parts of the world; [adv] in or to all parts of the world.

<sup>257</sup>**funding** [n] [uncountable] money provided by an organization or government for a particular purpose; the act of providing such money.

<sup>258</sup>**contract** [n] an official written agreement, especially one concerned with employment or selling something; [v] **1.** [intransitive, transitive] to become less or smaller; to make something become less or smaller, OPPOSITE: **expand**; **2.** [transitive] to get an illness; **3.** [transitive, often passive, intransitive] to make a legal agreement with somebody for them to work for you or provide you with a service; **4.** [intransitive] **contract to do something** to make a legal agreement to work for somebody or provide them with a service; **5.** [transitive] **contract a marriage/an alliance (with somebody)** to formally agree to marry somebody or form an alliance with somebody; **contract out (of something)** (*British English*) [phrasal verb] to formally agree that you will not take part in something; **contract something out (to somebody)** [phrasal verb] to arrange for work to be done by another company rather than your own.

I hardly<sup>259</sup> need to emphasize<sup>260</sup> that when resources<sup>261</sup> become scarce<sup>262</sup>, competition<sup>263</sup> intensifies<sup>264</sup> for what remains<sup>265</sup> available. To win a permanent position in scientific research, & the funds<sup>266</sup> to carry on<sup>267</sup> serious<sup>268</sup> work, you will have to be exceptionally<sup>269</sup> thoughtful<sup>270</sup> about your career choices. My hope is that this “pocket<sup>271</sup> mentor” will help you to become more introspective<sup>272</sup> about what it will take to succeed.

– ALBUQUERQUE, NM, Aug 1993 (updated in Jan 2010)

The past 17 years have seen revolutionary<sup>273</sup> changes in how we communicate<sup>274</sup> information. Virtually<sup>275</sup> all journals are available electronically<sup>276</sup>. Preprints can be published on the Internet before or without ever being refereed<sup>277</sup>. Overhead<sup>278</sup> projectors<sup>279 280</sup> have disappeared<sup>281</sup> from scientific meetings in favor<sup>282</sup> of LCD<sup>283</sup> projectors & laptop<sup>284</sup> computers<sup>285</sup>.

<sup>259</sup>**hardly** [adv] **1.** used to suggest that something is not likely or not reasonable; **2.** almost no; almost not; almost none; **3.** used especially after ‘can’ or ‘could’ & before the main verb, to emphasize that it is difficult to do something.

<sup>260</sup>**emphasize** [v] (*British English also emphasise*) to give special importance to something, SYNONYM: **stress**.

<sup>261</sup>**resource** [n] **1.** [countable, usually plural] a supply of something that a country, an organization or a person has & can use; **2.** [countable] something that can be used to help achieve an aim, especially as a part of work or study; **3.** (**resources**) [plural] personal qualities that help you deal with a situation.

<sup>262</sup>**scarce** [a] (**scarcer, scarcest**) if something is scarce, there is not enough of it & it is only available in small quantities.

<sup>263</sup>**competition** [n] **1.** [uncountable] (used especially about the world of business) a situation in which somebody/something tries to be more successful than somebody/something else, or tries to get something rather than let somebody/something else get it; **2.** (**the competition**) [singular] a person or business that is trying to be more successful than others; goods or services that are intended to be more successful than others; **3.** [uncountable, countable] (*ecology*) a situation in which animals, plants or other living things try to get resources, with the result that other animals, plants, etc. may not be able to get them; **4.** [countable] a contest to find out who is the best at something.

<sup>264</sup>**intensify** [v] [intransitive, transitive] to increase in degree or strength; to make something increase in degree or strength, SYNONYM: **heighten**.

<sup>265</sup>**remain** [v] (not usually used in the progressive tenses) **1.** *linking verb* to continue to be something; to be still in the same state or condition; **2.** [intransitive] **remain (of something)** to still be present after the other parts have been removed or used; to continue to exist; **3.** [intransitive] to still need to be done, said or dealt with; **4.** [intransitive] + **adv./prep.** to stay in the same place; to not leave; **it remains to be seen (whether/what, etc.), somethin remains to be seen** [idiom] used to say that you cannot yet know something.

<sup>266</sup>**fund** [n] **1.** (**funds**) [plural] money that is available to be spent; **2.** [countable] an amount of money that has been saved or has been made available for a particular purpose; **3.** [countable] a financial organization that invests money in a range of shares, etc. for a large number of people; **4.** [singular] **fund of something** a supply of something; [v] to provide money for something, usually something official, SYNONYM: **finance**.

<sup>267</sup>**carry on** [phrasal verb] (*especially British English*) to continue moving; **carry on (with something)** | **carry something on** [phrasal verb] to continue doing something.

<sup>268</sup>**serious** [a] **1.** important & worrying because of possible danger or risk; **2.** that must be treated as important & thought about carefully; **3.** thinking about things in a careful & sensible way; **4.** **serious about (doing) something** sincere about something.

<sup>269</sup>**exceptionally** [adv] **1.** used before an adjective or adverb to emphasize how strong or unusual the quality is; **2.** only in unusual circumstances.

<sup>270</sup>**thoughtful** [a] showing signs of careful thought.

<sup>271</sup>**pocket** [n] **1.** a small area or group that is different from its surroundings; **2.** a small empty space inside something; **3.** (*rather informal*) used to talk about the amount of money that you have to spend.

<sup>272</sup>**introspective** [a] tending to think a lot about your own thoughts, feelings, etc.

<sup>273</sup>**revolutionary** [a] **1.** [usually before noun] connected with political revolution; **2.** involving a great or complete change; [n] (plural **revolutionaries**) a person who starts or supports a revolution, especially a political one.

<sup>274</sup>**communicate** [v] **1.** [intransitive, transitive] to exchange information, news, ideas, etc. with somebody; **2.** [intransitive, transitive] to make your ideas, feelings, thoughts, etc. known to other people so that they understand them; **3.** [intransitive] to have a good relationship because you are able to understand & talk about your own & other people’s thoughts, feelings, etc.; **4.** [transitive, usually passive] **communicate something** to pass a disease from 1 person or animal to another.

<sup>275</sup>**virtually** [adv] **1.** almost or very nearly, so that any slight difference is not important; **2.** by the use of computer software that makes something appear to exist; **3.** by means of computers & computer networks.

<sup>276</sup>**electronically** [adv] in an electronic way; using a device that works in an electronic way.

<sup>277</sup>**referee** [v] **1.** (*also informal ref*) [intransitive, transitive] to act as the referee in a game; **2.** [transitive] **referee something** to read & check the quality of an academic article before it is published.

<sup>278</sup>**overhead** [adv] above your head; in the sky; [a] **1.** above your head; raised above the ground; **2.** [only before noun] connected with the general costs of running a business or an organization, e.g. paying for rent or electricity; [n] (*especially North American English*) (*also overheads especially in British English*) [uncountable] regular costs that you have when you are running a business or an organization, such as rent, electricity, wages, etc.

<sup>279</sup>**projector** [n] a piece of equipment for projecting photographs, films or computer slides onto a screen.

<sup>280</sup>**overhead projector** [n] (abbr., **OHP**) a piece of equipment that projects an image onto a wall or screen so that many people can see it.

<sup>281</sup>**disappear** [v] **1.** [intransitive] to stop existing, SYNONYM: **vanish**; **2.** [intransitive] to become impossible to see, SYNONYM: **vanish**; **3.** [intransitive] to become lost or impossible to find, SYNONYM: **vanish**.

<sup>282</sup>**favour** [n] (*US favor*) **1.** [countable] a thing that you do to help somebody; **2.** [uncountable] approval or support for somebody/something; in favor (of somebody/something) [idiom] **1.** supporting & agreeing with something/somebody; **2.** likely to produce a particular result, often in an unfair way; **3.** in exchange for another thing (because the other thing is better or you want it more); [v] **1.** to prefer 1 thing to another, especially a particular system, plan or way of doing something; **2.** to treat somebody/something better than others, especially in an unfair way; **3.** **favor something** to provide suitable conditions for something; to make it easier for something to happen.

<sup>283</sup>**LCD** [n] **1.** **liquid crystal display** (a way of showing information in electronic equipment. An electric current is passed through a special liquid & numbers & letters can be seen on a small screen.); **2.** lowest common denominator.

<sup>284</sup>**laptop** [n] (*also laptop computer*) a small computer that can work with a battery & be easily carried.

<sup>285</sup>**computer** [n] an electronic machine that can store, organize & find data, do calculations & control other machines.

Résumés are often distributed<sup>286 287</sup> electronically. This update of *A PhD Is Not Enough!* comes abreast<sup>288</sup> of these changes, though<sup>289</sup> the basic content of the 1993 original<sup>290</sup> remains timely<sup>291</sup>. The communications revolution cannot be ignored<sup>292</sup> but has not made it less important to be thoughtful<sup>293</sup> about choosing your career path or to respect<sup>294</sup> audiences<sup>295</sup> & readers<sup>296</sup>. I still attend<sup>297</sup> talks<sup>298</sup> that make me squirm<sup>299</sup> & struggle<sup>300</sup> to read sleep-inducing scientific articles. I hope attentive<sup>301</sup> readers of this book will reap<sup>302</sup> the rewards<sup>303</sup> of doing better.

– ALBUQUERQUE, NM, Jan 2010” – Feibelman, 2011, Preface: What This Book Is About, pp. xi–xvii

<sup>286</sup>**distribute** [v] **1.** [transitive, often passive] to give something, or a share of something, to a large number of people; **2.** [transitive] **distribute something** to send goods to shops & businesses so that they can be sold; **3.** [intransitive, transitive] to spread or spread something in a particular way.

<sup>287</sup>**distributed** [a] (+ **adv./prep.**) spread over a particular area; existing in a particular way. In computing, a **distributed system** is any system in which a number of individual computers are linked into a network & can work together.

<sup>288</sup>**abreast** [adv] next to somebody/something & facing the same way; **keep abreast of something** [idiom] to make sure that you know all the most recent facts about a subject.

<sup>289</sup>**though** [conjunction] **1.** despite the fact that, SYNONYM: **although**; **2.** used to add a fact or an opinion that makes the previous statement less strong or less important, SYNONYM: **but**; **as if/as though** [idiom] in a way that suggests something; [adv] however; used to add a fact or an opinion that contrasts with a statement that has been made or makes it less true or important. In spoken English, **though** as an adverb is often used at the end of a sentence. However, this can sound very informal & is best avoided in academic writing. Unlike ‘however’, **though** cannot be used as an adverb at the beginning of a sentence.

<sup>290</sup>**original** [a] **1.** [only before noun] present or existing from the beginning; 1st or earliest; **2.** new & interesting in a way that is different from anything that has existed before; able to produce new & interesting ideas; **3.** [usually before noun] painted, written, etc. by the artist rather than copied; [n] **1.** the earliest form of something, from which copies are later made; **2.** a book, text or play in the language in which it was 1st written; **in the original** [idiom] in the language in which a book, etc. was 1st written, before being translated.

<sup>291</sup>**timely** [a] happening at exactly the right time.

<sup>292</sup>**ignore** [v] **1.** **ignore something** to deliberately pay no attention to something, SYNONYM: **disregard**; **2.** **ignore something** to fail to consider an important aspect of something.

<sup>293</sup>**thoughtful** [a] showing signs of careful thought.

<sup>294</sup>**respect** [n] **1.** [countable] a particular aspect or detail of something; **2.** [uncountable, singular] polite behavior towards or reasonable treatment of somebody/something; **3.** [uncountable, singular] a feeling of admiration for somebody/something because of their good qualities or achievements; **in respect of something** [idiom] (*formal*) **1.** concerning; **2.** in payment for something; **with respect** [idiom] used when you are going to disagree, usually quite strongly, with somebody; **with respect to something** [idiom] concerning; [v] **1.** **respect something** to agree not to break a law or principle; **2.** to be careful not to do something that people would consider to be wrong; to treat somebody in a way that shows that you think they are important; **3.** [often passive] (not usually used in the progressive tenses) to have a good opinion of somebody/something; to admire somebody/something.

<sup>295</sup>**audience** [n] **1.** [countable + singular or plural verb] the people who are watching or listening to a play, concert, somebody speaking, etc.; **2.** [countable] a number of people or a particular group of people who watch, read or listen to the same thing; **3.** [countable] **audience with somebody** a formal meeting with an important person.

<sup>296</sup>**reader** [n] **1.** a person who is reading something; **2.** a person who reads a particular newspaper, magazine, etc.; **3.** (*computing*) an electronic device that reads data stored in 1 form & changes them into another form so that a computer can perform operations on them; **4.** (usually **Reader**) **reader (in something)** a senior teacher at a British university just below the rank of a professor.

<sup>297</sup>**attend** [v] **1.** [intransitive, transitive] to be present at an event; **2.** [intransitive, transitive] to go regularly to a place; **3.** [intransitive] (*formal*) to pay attention to something; **4.** [transitive] **attend something** (*formal*) to happen at the same time as, or as a result of, something; **5.** [transitive] **attend somebody** to be with somebody & help them; **attend to somebody/something** [phrasal verb] to deal with somebody/something; to take care of somebody/something.

<sup>298</sup>**talk** [v] **1.** [intransitive] to say things or have a conversation with somebody; to use words in order to give information or to express feelings or ideas; **2.** [intransitive, transitive] to use words; to say words in a language; [n] **1.** [countable] an informal speech or lecture on a particular subject; **2.** (**talks**) [plural] formal discussions between governments or organizations; **3.** [uncountable] (often in compounds) conversation or a way of speaking; **4.** [uncountable] stories & statements that suggest a particular thing might happen in the future; **5.** [countable] **talk (with somebody)** a conversation or discussion; **6.** [uncountable] words that are spoken, but without the necessary facts or actions to support them.

<sup>299</sup>**squirm** [v] **1.** [intransitive] to move around a lot making small twisting movements, because you are nervous, uncomfortable, etc., SYNONYM: **wriggle**; **2.** [intransitive] to feel very embarrassed or ashamed.

<sup>300</sup>**struggle** [n] **1.** [countable] a hard fight in which people try to obtain or achieve something, especially something that somebody else does not want them to have, SYNONYM: **battle**; **2.** [singular] **struggle to do something** something that is difficult for you to do or achieve, SYNONYM: **effort**; **3.** [countable] a physical fight between 2 people or groups, especially when 1 of them is trying to escape, or to get something from the other, SYNONYM: **fight**; [v] **1.** [intransitive] to try very hard to do something when it is difficult or when there are a lot of problems; **2.** [intransitive] to fight against somebody/something in order to prevent a bad situation or result; **3.** [intransitive] to compete or argue with somebody, especially in order to get something.

<sup>301</sup>**attentive** [a] **1.** reading, listening or watching carefully & with interest; **2.** helpful; making sure that people have what they need.

<sup>302</sup>**reap** [v] **reap something** to obtain something, especially something good, as a direct result of something that you have done.

<sup>303</sup>**reward** [n] **1.** [countable, uncountable] a thing that you are given, or something good that happens, because you have done something good, worked hard, etc.; **2.** [countable] an amount of money that is offered to encourage people to do something, such as help the police find a criminal, find something that is lost, etc.; [v] [often passive] to give something to somebody because they have done something good, worked hard, etc.

## Acknowledgments

“... numerous constructive<sup>304</sup> criticisms<sup>305</sup> of the 1st draft<sup>306</sup>.” [...] “... critical<sup>307</sup> readings<sup>308</sup> of the manuscript<sup>309</sup>.” [...] “... many editorial<sup>310</sup> improvements<sup>311</sup>.” – Feibelman, 2011, Acknowledgments, p. xix

## 1.1 Do You See Yourself in This Picture?

“A set of nonfiction<sup>312</sup> vignettes<sup>313</sup> illustrating<sup>314</sup> some of the ways that young scientists make their lives more unpleasant than necessary<sup>315</sup> or fail entirely<sup>316</sup> to establish themselves in a research career.”

“The brief stories in this chapter have a common<sup>317</sup> theme<sup>318</sup>: that understanding<sup>319</sup> & dealing<sup>320 321</sup> rationally<sup>322</sup> with the

<sup>304</sup>**constructive** [a] having a useful & helpful effect rather than being negative or with no purpose.

<sup>305</sup>**criticism** [n] 1. [uncountable, countable] the act of expressing disapproval of somebody/something & opinions about their faults or bad qualities; a statement showing disapproval; 2. [uncountable] the work or activity of analyzing & making fair, careful judgments about somebody/something, especially books, music, etc.

<sup>306</sup>**draft** [n] 1. [countable] a rough written version of something that is not yet in its final form; 2. (the draft) [singular] (US) = **conscription**; [v] (also **draught** especially in British English) 1. **draft something** to write the 1st rough version of something such as a letter, speech or book; 2. [usually passive] **be drafted** + **adv./prep.** to choose people & send them somewhere for a special task; 3. [usually passive] **be drafted (into something)** (US) = **conscript**.

<sup>307</sup>**critical** [a] 1. extremely important, e.g. because a future situation will be affected by it, SYNONYM: **crucial**; 2. involving making fair, careful judgments about the good & bad qualities of somebody/something, OPPOSITE: **uncritical**; 3. challenging traditional ideas in the study of society, literature, etc.; 4. (of a text) containing detailed notes & analysis by an expert; 5. **critical (of somebody/something)** expressing disapproval of somebody/something & saying what you think is bad about them/it; 6. used to describe a situation that is serious & uncertain & in which bad things could happen; 7. [only before noun] according to the judgment of people whose job is to write or broadcast their opinions about art, music, plays, etc.

<sup>308</sup>**reading** [n] 1. [uncountable] books or articles that are intended to be read; 2. [singular, uncountable] an act of reading something; 3. [uncountable] the activity of somebody who reads; 4. [countable] **reading (of something)** the particular way in which you understand something, such as a book or a situation, SYNONYM: **interpretation**; 5. [countable] 1 of the stages during which a bill must be discussed & accepted by a parliament before it can become law; 6. [countable] the amount or number shown on an instrument used for measuring something; 7. [countable] **reading (of something)** an event at which something is read to an audience for entertainment; a piece of literature that is read at such an event.

<sup>309</sup>**manuscript** [n] (abbr., **MS**) 1. [countable, uncountable] a copy of a book, piece of music, etc. before it has been printed; 2. [countable] a book, document or piece of music written by hand rather than typed or printed, especially a very old one.

<sup>310</sup>**editorial** [a] [usually before noun] connected with the task of preparing something such as a newspaper, a book, or a television or radio programme, to be published or broadcast; [n] an important article in a journal or a newspaper, that expresses the editor's opinion about an issue.

<sup>311</sup>**improvement** [n] 1. [uncountable] the act of making something better; the process of something becoming better; 2. [countable] a change in something that makes it better; something that is better than it was before.

<sup>312</sup>**nonfiction** [n] [uncountable] books, articles, or texts about real facts, people, & events, OPPOSITE: **fiction**.

<sup>313</sup>**vignette** [n] (formal) 1. a short piece of writing or acting that clearly shows what a particular person, situation, etc. is like; 2. a small picture or drawing, especially on the 1st page of a book.

<sup>314</sup>**illustrate** [v] 1. to make the meaning of something clearer by using examples, pictures, etc.; 2. to show that something is true or that a situation exists, SYNONYM: **demonstrate**; 3. [usually passive] to use pictures, photographs, diagrams, etc. in a book, etc.

<sup>315</sup>**unpleasant** [a] 1. not pleasant or comfortable, OPPOSITE: **pleasant**; 2. not kind, friendly or polite.

<sup>316</sup>**entirely** [adv] in every way possible, SYNONYM: **completely**.

<sup>317</sup>**common** [a] (**commoner**, **commonest**) (**more common** & **most common** are more frequent) 1. happening often; existing in large numbers or in many places, OPPOSITE: **rare**, **uncommon**; 2. [usually before noun] shared by or belonging to 2 or more people, groups or things, or by the people or things in a group; 3. [only before noun] not unusual or special, SYNONYM: **ordinary**; **be common/public knowledge** [idiom] to be something that everyone knows, especially in a particular community or group; **the common good** [idiom] the benefit or interests of everyone; [n] **have something in common** (of things, places, etc.) [idiom] to have the same features or characteristics; **have, etc. something in common (with somebody)** (of people) [idiom] to have the same interests & ideas as somebody else; **in common** [idiom] shared by everyone in a group.

<sup>318</sup>**theme** [n] the subject of a talk, piece of writing, exhibition, etc.; an idea that keeps returning a piece of research or a work of art or literature.

<sup>319</sup>**understanding** [n] 1. [uncountable, countable, usually singular] the fact or state of knowing or realizing something, e.g. what somebody/something is like, how or why people do things, how something happens or why something is important; 2. [uncountable] kindness & sympathy, often towards somebody who has different views or who has behaved badly; 3. [countable, usually singular] an agreement, often not written in a contract, that people will help each other or that something will happen in a particular way; 4. [uncountable, countable] **understanding (of something)** (is that ...) the particular way in which somebody understands something.

<sup>320</sup>**deal** [v] **deal in something** [phrasal verb] to buy & sell a particular product, SYNONYM: **trade**; **deal with somebody** [phrasal verb] to take appropriate action, according to who you are talking to, managing or looking after, SYNONYM: **handle**; **deal with somebody/something** [phrasal verb] to do business with a person, a company or an organization; **deal with something** [phrasal verb] 1. to take action in order to solve a problem or complete a task; 2. to be about a particular subject; [n] 1. [countable] an agreement, especially in business, on particular conditions for buying or doing something; 2. [singular] **a good/great deal (of something)** much; a lot; **strike a bargain/deal** [idiom] to make an agreement with somebody in which both sides have an advantage.

<sup>321</sup>**dealing** [n] 1. (**dealings**) [plural] business activities; the relations that you have with somebody in business; 2. [uncountable, countable] buying & selling; 3. [uncountable] **dealing (between A & B)** a way of doing business or making agreements with somebody.

<sup>322</sup>**rational** [a] 1. (of behavior or ideas) based on reason rather than emotions, OPPOSITE: **irrational**; 2. (of a person) able to think clearly & make decisions based on reason rather than emotions, SYNONYM: **reasonable**, OPPOSITE: **irrational**.



realities<sup>323</sup> of a life in science are as important to science survival as being bright<sup>324</sup>. Once you leave graduate school, the clock<sup>325</sup> is ticking<sup>326</sup>. Unlike a fine wine<sup>327</sup>, you do not have many years to mature<sup>328</sup>. As a young professional<sup>329</sup>, you must be able to select appropriate<sup>330</sup> research problems, you have to finish<sup>331</sup> projects in a timely<sup>332</sup> manner<sup>333</sup>, & you ought to be giving compelling<sup>334</sup> tasks & publishing<sup>335 336</sup> noteworthy<sup>337</sup> papers<sup>338</sup>. When job opportunities<sup>339</sup> present themselves,

<sup>323</sup>**reality** [n] (plural **realities**) **1.** [uncountable] the true situation & the problems that actually exist in the world, especially in contrast to how people would like it to be; **2.** [countable] a thing that is actually experienced or seen, in contrast to what people might imagine; **3.** [uncountable] **reality television/TV/shows/series/contestants** television/shows, etc. that use real people (not actors) in real situations, presented as entertainment; **in reality** [idiom] used to say that a situation is different from what has just been said or from what people believe.

<sup>324</sup>**bright** [a] (**brighter, brightest**) **1.** full of light; shining strongly; **2.** (of a color) strong & easy to see; **3.** intelligent; quick to learn; **4.** giving reason to believe that good things will happen; likely to be successful.

<sup>325</sup>**clock** [n] an instrument for measuring & showing time, in a room or on the wall of a building (not worn or carried like a watch). A **biological clock** is a natural system in living things that controls regular physical activities such as sleeping; **around/round the clock** [idiom] all day & all night without stopping; **turn/put the clock back** [idiom] (*often disapproving*) to return to a situation that existed in the past, or to old-fashioned methods or ideas.

<sup>326</sup>**tick** [v] **1.** [transitive] (*British English*) (*North American English check*) to put a mark next to an item on a list, an answer, etc.; **2.** [intransitive] (of a clock, etc.) to make short, light, regular repeated sounds to mark time passing; [n] **1.** (*British English*) (*North American English check mark*; **check** a mark put beside a sum or an item on a list, usually to show that it has been checked or done or is correct; **2.** a small insect that bites humans & animals & sucks their blood. There are several types of tick, some of which can carry diseases.

<sup>327</sup>**wine** [n] [uncountable, countable] a common alcoholic drink made from the juice of grapes.

<sup>328</sup>**mature** [a] (**maturer** is occasionally used instead of **more mature**) **1.** fully grown & developed physically, OPPOSITE: **immature**; **2.** behaving in a sensible way, as is expected of an adult, OPPOSITE: **immature**; **3.** (of a system or organization) having reached an advantage stage. A **mature** economy, industry or market has developed to a point where it is unlikely that it will grow further; **4.** created later in somebody's life & showing greater understanding & skill; [v] **1.** [intransitive] to become fully grown or developed physically; **2.** [intransitive] to develop emotionally & behave like a sensible adult; **3.** [intransitive] (of a system or organization) to reach an advanced stage.

<sup>329</sup>**professional** [a] **1.** [only before noun] connected with a job that needs special training or skill, especially one that needs a high level of education; **2.** (of people) having a job that needs special training & a high level of education; **3.** showing that somebody is well trained & extremely skilled, SYNONYM: **competent**; **4.** suitable or appropriate for somebody working in a particular profession; **5.** doing something as a paid job rather than just for pleasure; [n] a person who does a job that needs special training & a high level of education.

<sup>330</sup>**appropriate** [a] suitable, acceptable or correct for the particular circumstances; [v] **1. appropriate something** to start to use something that belongs to a different time, place or culture; **2. appropriate something** to make somebody's idea, property or money for your own use, especially without permission; **3. appropriate something** to take something from somebody, legally & often by force, SYNONYM: **size**; **4. appropriate something** to take or give something, especially money, for a particular purpose.

<sup>331</sup>**finish** [v] **1.** [transitive, intransitive] to stop doing something or making something because it is complete; **2.** [intransitive, transitive] to come to an end; to bring something to an end; **finish somebody/something off** [phrasal verb] (*informal*) to destroy somebody/something, especially somebody/something that is badly injured or damaged; **finish something off** [phrasal verb] to do the last part of something; to make something end by doing 1 last thing; **finish up** ... [phrasal verb] (*British English*) to be in a particular state or at a particular place after a series of events; [n] [usually singular] **1.** the last part or the end of something; **2.** the last covering of paint, etc. that is put onto the surface of something; the condition of the surface; **fight to the death/finish** [idiom] to fight until 1 of the 2 people or groups is dead, or until 1 person or group defeats the other.

<sup>332</sup>**timely** [a] happening at exactly the right time.

<sup>333</sup>**manner** [n] **1.** [singular] the way that something is done or happens; **2.** [singular] the way that somebody behaves towards other people; **3.** (**manners**) [plural] behavior that is considered to be polite in a particular society or culture; **4.** (**manners (of somebody/something)**) [plural] the habits & customs of a particular group of people; **all manner of somebody/something** [idiom] many different types of people or things; **in the manner of somebody/something** [idiom] in a style that is typical of somebody/something.

<sup>334</sup>**compelling** [a] **1.** that makes you think it is true or valid; **2.** making you pay attention through being so interesting & exciting; **3.** that cannot be resisted.

<sup>335</sup>**publish** [v] **1.** [transitive] **publish something** to produce a book, magazine, etc. & sell it to the public; **2.** [transitive] to print a letter, an article, etc. in a newspaper or magazine; **3.** [transitive, intransitive] (of an author) to have your work printed in a newspaper, magazine, etc., or printed & sold to the public; **4.** [transitive] to make information available to the public, SYNONYM: **release**.

<sup>336</sup>**publishing** [n] [uncountable] the profession, business or activity of preparing books, articles, etc. & selling them or making them available to the public.

<sup>337</sup>**noteworthy** [a] deserving to be noticed or to receive attention because it is unusual, important or interesting, SYNONYM: **significant**.

<sup>338</sup>**paper** [n] **1.** [uncountable] (often in compounds) material made in thin sheets, used for writing, drawing, covering things, etc.; **2.** [uncountable] an academic article about a particular subject that is written by & for experts; **3.** [countable] a newspaper; **4.** (**papers**) [plural] pieces of paper with writing on them, such as letters, pieces of work or private documents; **5.** [countable] (*North American English*) a piece of written work done by a student; **6.** [countable] (*British English*) a set of exam questions on a particular subject; the answers that people write to the questions; **7.** (**papers**) [plural] official documents that prove your identity, give you permission to do something, etc.; **on paper** [idiom] **1.** judged from written information only, but not proved in practice; **2.** when you put something on paper, you write it down.

<sup>339</sup>**opportunity** [n] (plural **opportunities**) [countable, uncountable] a situation or time that makes it possible to do or achieve something, SYNONYM: **change**. As an uncountable noun, **opportunity** is used to talk about the existence or extent of opportunities; **at the earliest opportunity** [idiom] as soon as possible.

you should be able to assess<sup>340</sup> their value realistically<sup>341</sup>. Romanticizing<sup>342</sup> your prospects<sup>343</sup> is a major mistake & is likely to have serious<sup>344</sup> consequences<sup>345</sup>, not excluding<sup>346 347</sup> dropping out<sup>348 349</sup> of scientific life prematurely<sup>350</sup>. The 1st story is an excerpt<sup>351</sup> from my own scientific beginnings<sup>352</sup>. The others are also nonfiction, though I have altered<sup>353</sup> locations<sup>354</sup> & personal<sup>355</sup> characteristics<sup>356</sup> to avoid<sup>357</sup> invading<sup>358</sup> the privacy<sup>359</sup> of the protagonists<sup>360</sup>. I have deliberately<sup>361</sup> identified<sup>362</sup>

<sup>340</sup>**assess** [v] **1.** to make a judgment about the nature or quality of somebody/something; **2.** to calculate the amount or value of something, SYNONYM: **estimate**.

<sup>341</sup>**realistically** [adv] **1.** used to say what you think can actually be achieved in a particular situation; **2.** in a way that shows that somebody accepts in a sensible way what it is actually possible to do or achieve.

<sup>342</sup>**romanticize** [v] (*British English also romanticise*) [transitive, intransitive] **romanticize (something)** to make something seem more attractive or interesting than it really is.

<sup>343</sup>**prospect** [n] **1.** [uncountable, singular] the possibility that something will happen; **2.** [singular] an idea of what might or will happen in the future; **3. (prospects)** [plural] the chances of being successful.

<sup>344</sup>**serious** [a] **1.** important & worrying because of possible danger or risk; **2.** that must be treated as important & thought about carefully; **3.** thinking about things in a carefully & sensible way; **4. serious about (doing) something** sincere about something.

<sup>345</sup>**consequence** [n] **1.** [countable] (often plural) a result of something that has happened; **2.** [uncountable] importance; **in consequence (of something)** [idiom] as a result of something.

<sup>346</sup>**exclude** [v] **1.** to deliberately not include something in what you are doing or considering, OPPOSITE: **include**; **2.** to prevent somebody/something from entering a place or taking part in something. In British English, if a school **excludes** a student, it does not allow the student to attend because of bad behavior.; **3. exclude something** to decide that something is not possible or is not the cause of something, OPPOSITE: **include**.

<sup>347</sup>**excluding** [prep] not including, OPPOSITE: **including**.

<sup>348</sup>**drop out** [phrasal verb] **drop out (of something)** **1.** to no longer take part in or be part of something; **2.** to leave school, college, etc. without finishing your studies; **3.** to reject the ideas & ways of behaving that are accepted by the rest of society.

<sup>349</sup>**dropout** [n] **1.** a person who leaves school or college before they have finished their studies; **2.** a person who rejects the ideas & ways of behaving that are accepted by the rest of society.

<sup>350</sup>**premature** [a] **1.** happening before the normal or expected time; **2.** (of a birth or a baby) happening or being born before the normal length of pregnancy has been completed; **3.** happening or made too soon.

<sup>351</sup>**excerpt** [n] **excerpt (from something)** a short piece of writing, music, film, etc. taken from a longer whole.

<sup>352</sup>**beginning** [n] **1.** [countable, usually singular] the time when something starts; the 1st part of an event or story. **At the beginning (of something)** is used for the time & place when something begins. **In the beginning** means **at 1st**, & suggests a contrast with a later situation; **2. (beginnings)** [plural] the 1st or early ideas, signs or stages of something; **the beginning of the end** [idiom] the 1st sign of something ending.

<sup>353</sup>**alter** [v] [transitive, intransitive] to make somebody/something different; to become different.

<sup>354</sup>**location** [n] **1.** [countable] a place where something happens or exists; the position of something; **2.** [countable, uncountable] a place outside a film studio where scenes of a film are made; **3.** [uncountable] **location of something** the act of finding the position of somebody/something; **4.** [countable] (*computing*) a position in computer memory.

<sup>355</sup>**personal** [a] **1.** [only before noun] your own; not belonging to or connected with anyone else; **2.** [only before noun] connected with individual people, especially their feelings, characters & relationships; **3.** not connected with a person's job or official position; **4.** [only before noun] done by a particular person rather than by somebody who is acting for them; **5.** [only before noun] made or done for a particular person rather than for a large group of people or people in general; **6.** [only before noun] connected with a person's body; **7.** connected with a particular person's character, appearance or private life in a way that is offensive.

<sup>356</sup>**characteristic** [n] **characteristic (of something/somebody)** a typical feature or quality that something/somebody has; [a] very typical of something/somebody.

<sup>357</sup>**avoid** [v] **1.** to prevent something bad from happening; **2.** to choose not to do something; to put somebody in a situation where they do not have to do something. Do not use **avoid** with an infinitive. Use **avoid + -ing** instead.; **3. avoid somebody/something** to keep away from somebody/something; **4. avoid something** to prevent yourself from hitting something.

<sup>358</sup>**invade** [v] **1.** [intransitive, transitive] to enter a country, town, etc. using military force in order to take control of it; **2.** [transitive] **invade something** to spread into a living thing or body part; **3.** [transitive] **invade something** (of an animal or plant) to move or spread into a place in large numbers; **4.** [transitive] **invade something** to disturb something or have an unpleasant effect on it; **5.** [transitive] **invade something** to enter a place, situation or area of activity in large numbers, especially in a way that causes damage or confusion.

<sup>359</sup>**privacy** [n] [uncountable] **1. privacy (of somebody)** the state of being free from the attention of the public; **2.** the state of being alone & not watched or disturbed by other people.

<sup>360</sup>**protagonist** [n] **1. protagonist (of something)** the main character in a play, film or book; **2.** 1 of the main people in a real event, especially a competition, battle or struggle; **3. protagonist (of something)** an active supporter of a policy or movement, especially one that is trying to change something, SYNONYM: **advocate, champion**.

<sup>361</sup>**deliberately** [adv] on purpose rather than by accident, SYNONYM: **intentionally**.

<sup>362</sup>**identify** [v] **1.** to find or discover somebody/something; **2.** to recognize somebody/something & be able to say who or what they are; **3.** to make it possible to recognize who or what somebody/something is; **identify with somebody** [phrasal verb] to feel that you can understand & share the feelings of somebody else; **identify somebody/something with somebody/something** [phrasal verb] to consider somebody/something to be the same as somebody/something else, SYNONYM: **equate**; **be identified with somebody/something** | **identify yourself with somebody/something** [phrasal verb] to have a close association or connection with somebody/something.



the various characters<sup>363</sup> with initials<sup>364</sup>, rather than names, to avoid any ethnic<sup>365</sup> implications<sup>366</sup>.” – Feibelman, 2011, pp. 1–2

### 1.1.1 What Do Scientists Do? Technique Versus Problem Orientation

<sup>367</sup> <sup>368</sup> <sup>369</sup> “Virtually all classroom<sup>370</sup> work & much of what happens in a typical<sup>371</sup> thesis project is aimed<sup>372</sup> at developing<sup>373</sup> <sup>374</sup> a student’s technical skills. But although the success of your research efforts<sup>375</sup> may depend heavily<sup>376</sup> on designing a piece of apparatus<sup>377</sup> or a computer code, & on making it work properly<sup>378</sup>, *no technical skill is worth more than knowing how to select exciting research projects*. Regrettably<sup>379</sup>, this vital<sup>380</sup> ability<sup>381</sup> is almost never taught. When I signed on with a research adviser in my 1st year of graduate school, I was thrilled<sup>382</sup> to be given a problem to work in the physics of the

<sup>363</sup>**character** [n] **1.** [countable, usually singular, uncountable] the way that something/somebody is; 1 or more qualities or features that cause something/somebody to be a particular way, SYNONYM: **nature**; **2.** [uncountable] (*approving*) strong personal qualities such as the ability to deal with difficult situations; **3.** [countable, uncountable] the opinion that people have of you, particularly of whether you can be trusted or relied on, SYNONYM: **reputation**; **4.** [countable] a person or an animal in a story, play or film; **5.** [countable] a letter, sign, mark or symbol used in writing, printing or computers; **6.** [countable] (*biology*) a characteristic, especially one that helps you identify a species; **out of character** [idiom] not typical of a person’s character.

<sup>364</sup>**initials** [n] [plural] the 1st letters of all the names of a person or thing.

<sup>365</sup>**ethnic** [a] connected with or belonging to a race or people that shares a cultural tradition.

<sup>366</sup>**implication** [n] [countable, usually plural] **implication (of something) (for something)** a possible effect or result of an action or a decision.

<sup>367</sup>**technique** [n] **1.** [countable] a particular way of doing something that involves using a special skill or process; **2.** [uncountable, singular] a person’s skill or ability in a particular activity.

<sup>368</sup>**versus** [prep] (abbr., **v**, **vs**) **1.** used to compare 2 different numbers, ideas, choices, etc.; **2.** (*law*) used to show that 2 sides are against each other.

<sup>369</sup>**orientation** [n] **1.** [uncountable, countable] the type of aims or interests that a person or an organization has; the act of directing your aims towards a particular thing; **2.** [uncountable, countable] a person’s basic beliefs or feelings about a particular subject; **3.** [uncountable, countable] **sexual orientation** whether a person is attracted to men, women or both; **4.** [countable] the direction in which an objects faces.

<sup>370</sup>**classroom** [n] a room where a class of children or students is taught. The word **classroom** is often used to talk about the practice & methods of teaching.

<sup>371</sup>**typical** [a] **1.** having the usual qualities or features of a particular type of person, thing or group, OPPOSITE: **atypical**; **2.** happening in the usual way; showing what something is usually like; **3.** behaving in the way that you expect.

<sup>372</sup>**aim** [n] the purpose of doing something; what somebody is trying to achieve; **take aim at somebody/something** [idiom] to direct your criticism at somebody/something; [v] **1.** [transitive] **be aimed at (doing) something** to have the intention of achieving something; **2.** [intransitive, transitive] to try or plan to achieve something; **3.** [transitive, usually passive] **aim something at somebody** to say or do something that is intended to influence or affect a particular person or group.

<sup>373</sup>**develop** [v] **1.** [intransitive, transitive] to gradually grow or become bigger, more advanced or stronger; to make something do this; **2.** [transitive] to think of or produce a new method, system, product, etc. & make it successful; **3.** [transitive] to make an idea or a theory clearer & more useful by explaining it further, SYNONYM: **elaborate**; **4.** [transitive] **develop something** to start or have a skill, ability, quality, etc. that becomes better & stronger; **5.** [intransitive, transitive] **develop (something)** to begin to have something such as a disease or a problem; (of a disease or problem) to start to affect somebody/something; **6.** [transitive] **develop something** to build new houses, factories, etc. on an area of land, especially land that was not actively being used before; **7.** [transitive] **develop something** to treat film which has been used to take photographs with chemicals so that the pictures can be seen.

<sup>374</sup>**developing** [a] [only before a noun] **1.** a developing country, region or society is poor, & trying to make its industry & economic system more advanced; **2.** becoming bigger, stronger or more advanced.

<sup>375</sup>**effort** [n] **1.** [uncountable, countable] the physical or mental energy that you need to do something; something takes takes a lot of energy; **2.** [countable] an attempt to do something, especially when it is difficult to do; **3.** [countable] (usually after a noun) a particular activity that a group of people organizes in order to achieve something.

<sup>376</sup>**heavily** [adv] **1.** to a great degree; in large amounts; **2.** in a way that is difficult to accept & deal with.

<sup>377</sup>**apparatus** [n] **1.** [uncountable] the tools or other pieces of equipment that are needed for a particular activity or task; **2.** [countable, usually singular] the structure of a system or an organization, particularly that of a political party or a government; **3.** [countable, usually singular] (*specialist*) a system of organs in the body; **4.** [countable, usually singular] a collection of notes & other material that accompanies a text.

<sup>378</sup>**properly** [adv] **1.** (*especially British English*) in a way that is correct &/or appropriate; **2.** in a way that is socially or morally acceptable, OPPOSITE: **improperly**; **3.** in the strict sense.

<sup>379</sup>**regretably** [adv] (*formal*) used to describe something that you are sorry about & wish had not happened.

<sup>380</sup>**vital** [a] **1.** necessary or essential in order for something to succeed or exist; **2.** [only before noun] connected with or necessary for staying alive.

<sup>381</sup>**ability** [n] (plural **abilities**) **1.** [singular] the fact that somebody/something is able to do something, OPPOSITE: **inability**; **2.** [uncountable, countable] a level of skill or intelligence.

<sup>382</sup>**thrilled** [a] very excited & pleased.

upper<sup>383</sup> atmosphere<sup>384</sup>. That I had no idea what motivated<sup>385 386</sup> the problem did not prevent<sup>387</sup> me from carrying out<sup>388</sup> an analysis<sup>389</sup>, on a supercomputer<sup>390</sup> of the day, & publishing my 1st paper at the age of 22. For my thesis, I consciously<sup>391</sup> switched<sup>392</sup> to a project that would require learning the tools of modern<sup>393</sup> quantum physics<sup>394</sup>, but again I found myself assimilating<sup>395</sup> technical skills without ever grasping<sup>396</sup> the significance<sup>397</sup> of the problem, without understanding how or whether<sup>398</sup> it was at the cutting edge<sup>399 400</sup> of science. This way of working became a habit<sup>401</sup>, one that seriously<sup>402</sup> threatened<sup>403</sup> my career<sup>404</sup>. My 1st 7 publications were in 7 different areas of physics. In each case, I relied<sup>405</sup> on a senior<sup>406</sup> scientist to tell me what would be an interesting problem to work on; then I would carry out the task. I assume<sup>407</sup> it was

<sup>383</sup>**upper** [a] [only before noun] **1.** located above something else, especially something of the same type or the other of a pair, OPPOSITE: **lower**; **2.** at or near the top of something, OPPOSITE: **lower**; **3.** (of a place) located away from the coast, on high ground or towards the north of an area, OPPOSITE: **lower**; **gain, get, have, etc. the upper hand** [idiom] to get an advantage over somebody so that you are in control of a particular situation.

<sup>384</sup>**atmosphere** [n] **1. (the atmosphere)** [singular] the mixture of gases that surrounds the earth; **2.** [countable] a mixture of gases that surrounds another planet or star; **3.** [countable] the air in a room; the air around a place; **4.** [countable, usually singular, uncountable] the feeling or mood that exists in a particular place or situation; a feeling between 2 people or in a group of people; **5. (abbr., atm)** [countable] (*physics*) a unit of measurement of pressure, equal to the mean pressure at sea level.

<sup>385</sup>**motivate** [v] **1.** [often passive] to be the reason why somebody does something or behaves in a particular way; **2.** to make somebody want to do something, especially something that involves hard work & effort.

<sup>386</sup>**motivated** [a] **1. racially/politically/ideologically, etc. motivated** done for racial, political, etc. reasons; **2.** wanting to do something, especially something that involves hard work & effort.

<sup>387</sup>**prevent** [v] to stop something from existing or happening; to stop somebody/something from doing something.

<sup>388</sup>**carry something out** [phrasal verb] **1.** to do & complete a task; **2.** to do something that you have said you will do or have been asked to do.

<sup>389</sup>**analysis** (plural **analyses**) **1.** [uncountable, countable] the detailed study or examination of something in order to understand more about it; the result of the study; **2.** [uncountable, countable] a careful examination of a substance in order to find out what it consists of; **3.** [uncountable] = **psychoanalysis**; **in the final/last analysis** [idiom] used to say what is most important after everything has been discussed or considered.

<sup>390</sup>**supercomputer** [n] a powerful computer with a large amount of memory & a very fast central processing unit.

<sup>391</sup>**consciously** [adv] **1.** if somebody does something consciously, they are aware of doing it, OPPOSITE: **unconsciously**; **2.** deliberately.

<sup>392</sup>**switch** [v] **1.** [intransitive, transitive] to change from 1 thing to another; too make something do this; **2.** [transitive] to exchange 1 thing for another; **switch off/on** | **switch something off/on** [phrasal verb] to turn a light, machine, etc. off/on by pressing a button or switch; [n] **1.** a small device that you press or move up & down in order to turn a piece of electrical equipment on & off; **2. switch (in/of something) (from A to B)** a change from 1 thing to another, especially when this is sudden & complete.

<sup>393</sup>**modern** [a] **1.** [usually before noun] of the present time or recent times, SYNONYM: **contemporary**; **2.** using the most recent technology, designs, materials, etc., SYNONYM: **up to date**; **3.** [usually before noun] (of styles in art, music, fashion, etc.) new & intended to be different from traditional styles, SYNONYM: **contemporary**; **4.** (of ways of behaving or thinking) new & not always accepted by most members of society, OPPOSITE: **traditional**; **5.** (of a language) in the form that is used at the present time, as opposed to any earlier form, OPPOSITE: **ancient**.

<sup>394</sup>**quantum physics** [n] [uncountable] the branch of science that investigates the principles of quantum theory to understand the behavior of particles at the atomic & subatomic level.

<sup>395</sup>**assimilate** [v] **1.** [intransitive, transitive] to become a part of a country or community rather than remaining in a separate group; to allow or cause people to do this; **2.** [transitive] **assimilate something** (of the body or any biological system) to absorb or take in a substance; **3.** [transitive] **assimilate something** to think deeply about something & understand it fully, so that you can use it, SYNONYM: **absorb**; **4.** [transitive, often passive] **assimilate something (into/to something)** to accept an idea, information or activity; to make it fit into something.

<sup>396</sup>**grasp** [v] **1.** to understand something completely; **2. grasp an opportunity** to take an opportunity without hesitating & use it; **3. grasp somebody/something** to take a firm hold of somebody/something, SYNONYM: **grip**; [n] [usually singular] **1.** a person's understanding of a subject; **2.** a firm hold of somebody/something or control over somebody/something; **3.** the ability to get or achieve something.

<sup>397</sup>**significance** [n] [uncountable, countable] **1.** the importance of something, especially when this has an effect on what happens in the future, OPPOSITE: **insignificance**; **2. significance (of something)** the meaning of something; **3.** (also **statistical significance** *statistics*) the extent to which a result is different from what would be expected from random variation or errors.

<sup>398</sup>**whether** [conjunction] **1.** used to express a doubt or choice between 2 possibilities; **2.** used to show that something is true in either of 2 cases.

<sup>399</sup>**cutting edge** [n] [singular] **1. the cutting edge (of something)** the newest, most advanced stage in the development of something; **2.** an aspect of something that gives it an advantage.

<sup>400</sup>**cutting-edge** [a] at the newest, most advanced stage in the development of something.

<sup>401</sup>**habit** [n] **1.** [countable, uncountable] something that you do often & almost without thinking about it, especially something that is difficult to change or stop; a person's usual behavior; **2.** [countable] a typical way of behaving that something has; the fact that somethings tends to happen in a particular way.

<sup>402</sup>**seriously** [adv] **1.** to a degree that is important & worrying; **2.** carefully & sincerely; **take somebody/something seriously** [idiom] to think that somebody/something is important & deserves attention & respect.

<sup>403</sup>**threaten** [v] **1.** [transitive] to say that you will cause trouble, hurt somebody, etc. if you do not get what you want; **2.** [transitive] to be a danger to something; to be likely to harm something, SYNONYM: **endanger**; **3.** [intransitive] to seem likely to happen or cause something unpleasant.

<sup>404</sup>**career** [n] **1.** the period of time that you spend in your life working or doing a particular thing; **2.** the series of jobs that a person has in a particular area of work, usually involving more responsibility as time passes.

<sup>405</sup>**rely** [v] **rely on/upon somebody/something** **1.** to need or depend on somebody/something; **2.** to trust or have confidence in somebody/something.

<sup>406</sup>**senior** [a] **1.** having a high rank in an organization or a profession, OPPOSITE: **junior**; **2.** [only before noun] older, especially having now required form work; **3.** [only before noun] (*British English*) (of a school or part of a school) for children over the age of 11 or 13; [n] (*especially North American English*) an older person, especially somebody who has now retired from work; **2.** a person who has a higher rank in an organization or a profession; **3.** (in the US & some other countries) a student in the last year at a high school or college.

<sup>407</sup>**assume** [v] **1.** to think or accept that something is true but without having proof of it; **2. assume something** to begin to have a particular quality, appearance or importance, SYNONYM: **take on something**; **3. assume something** to take or begin to have power or responsibility,

my ability to complete<sup>408</sup> projects that impressed<sup>409 410</sup> my superiors<sup>411</sup> to keep me employed<sup>412</sup>. It certainly<sup>413</sup> wasn't my depth<sup>414</sup> in any field<sup>415</sup>.

4 years & 2 postdoctoral positions after earning a PhD – still having little sense of what I wanted to learn as a scientist – I was on the job market. More than anything else, I need good recommendations<sup>416</sup> from faculty<sup>417</sup> at the university where I was employed. I was asked to give the weekly<sup>418</sup> solid-state<sup>419</sup> physics seminar<sup>420</sup> & realized<sup>421</sup>, at best dimly<sup>422</sup>, that my performance<sup>423</sup> in this venue<sup>424</sup> was either going to make or break me as a scientist.

The talks I was giving at this point in my career reflected<sup>425</sup> my approach<sup>426</sup> to science. There was little in the way

SYNONYM: **take**.

<sup>408</sup>**complete** [a] **1.** including all of the parts of something, OPPOSITE: **incomplete**; **2.** [usually before noun] used when you are emphasizing something, to mean 'to the greatest degree possible', SYNONYM: **total**; **3.** [not before noun] finished, OPPOSITE: **incomplete**; **4.** [not before noun] **complete with something** including something as an important part or feature; [v] **1. complete something** to finish doing something; **2. complete something** to write all the information you are asked for on a form, SYNONYM: **fill something in**; **3. complete something** to make something whole.

<sup>409</sup>**impress** [v] [transitive, intransitive] if a person or thing impresses you, you feel admiration for them or it; **impress something on/upon somebody** [phrasal verb] to make somebody understand how important something is by emphasizing it; **impress something/itself on/upon somebody** [phrasal verb] to have a great effect on something, especially somebody's mind or imagination.

<sup>410</sup>**impressed** [a] feeling admiration for somebody/something because you think they are particularly good.

<sup>411</sup>**superior** [a] **1.** better in quality than somebody/something else, OPPOSITE: **inferior**; **2.** greater than somebody/something else; **3.** higher in rank, importance or position, OPPOSITE: **inferior**; **4.** (*anatomy*) further above or out; higher in position, OPPOSITE: **inferior**; [n] (**somebody's**) **superior** a person of higher rank or position.

<sup>412</sup>**self-employed** [a] **1.** working for yourself & not employed by a company, etc.; **2. (the self-employed)** [n] [plural] people who work for themselves & are not employed by a company, etc.

<sup>413</sup>**certainly** [adv] without doubt, SYNONYM: **definitely**.

<sup>414</sup>**depth** [n] **1.** [countable, uncountable] the distance from top or surface to the bottom of something; how deep something is; **2.** [uncountable] **depth (of something)** the fact of having or providing a lot of information or knowledge; **3.** [uncountable] **depth (of something)** the fact of being very important or serious; **4.** [uncountable] the quality in an image that makes it appear not to be flat; **the depths of something** [idiom] **1.** the deepest part of something; **2.** the most serious or extreme part of something; **in depth** [idiom] in a detailed & thorough way.

<sup>415</sup>**field** [n] **1.** [countable] a particular subject or activity that somebody works in or is interested in, SYNONYM: **area**; **2.** [countable] an area of land in the country used for growing crops or keeping animals in, usually surrounded by a fence, etc.; **3.** [countable] (usually in compounds) a large area of land covered with the thing mentioned; an area from which the thing mentioned is obtained; **4.** [countable] (usually in compounds) an area of land used for the purpose mentioned; **5.** [countable] (usually used as an adjective) the fact of people doing practical work or study, rather than working in a library or laboratory; **6.** [singular + singular or plural verb] all the people or products competing in a particular area of business or activity; **7.** [countable] (usually in compounds) an area within which the force mentioned has an effect; **8.** [countable] the area within which objects can be seen from a particular point; **9.** [countable] part of a record that is a separate item of data; **leave the field open to somebody/something** [idiom] to enable somebody/something to be successful in a particular area of activity because other people or groups have given up competing with them.

<sup>416</sup>**recommendation** [n] an official suggestion about the best thing to do.

<sup>417</sup>**faculty** [n] (plural **faculties**) **1.** [countable] a physical or mental ability, especially one that people are born with; **2.** [countable] **faculty (of something)** a department or group of related departments in a college or university; **3.** [countable + singular or plural verb] all the teachers in a faculty of a college or university; **4.** [countable, uncountable] (*North American English*) all the teachers of a particular university or college.

<sup>418</sup>**weekly** [a] happening, done or published once a week or every week.

<sup>419</sup>**solid-state** [a] (*specialist*) using or containing solid semiconductors.

<sup>420</sup>**seminar** [n] **1.** a class at a university or college when a small group of students & a teacher discuss or study a particular topic; **2.** a meeting for discussion or training.

<sup>421</sup>**realize** [v] (*British English also realise*) **1.** [transitive, intransitive] (not used in the progressive tenses) to understand or become aware of a particular fact or situation; **2.** [transitive] **realize something** to achieve something important; **3.** [transitive, usually passive] **be realized** to happen or become real; **4.** [transitive] **realize something** to make a profit or an amount of money, SYNONYM: **make**; **5.** [transitive] **realize your assets** to sell things that you own, e.g. property, in order to get the money that you need for something; **6.** [transitive] **realize something** to give actual or physical form to something.

<sup>422</sup>**dimly** [adv] not very brightly or clearly.

<sup>423</sup>**performance** [n] **1.** [uncountable, countable] how well or badly you do something; how well or badly something works; **2.** [uncountable, singular] **performance of something** the action or process of performing a task or function; **3.** [countable] **performance (of something)** an act of presenting a play, concert or some other forms of entertainment; **4.** [countable] an act of performing a song, a piece of music, or a role in a play or film.

<sup>424</sup>**venue** [n] a place where people meet for an organized event, e.g. a concert, sporting event or conference.

<sup>425</sup>**reflect** [v] **1.** [transitive] to show or be a sign of what something is like or how somebody thinks or feels; **2.** [transitive] to throw back light, heat, sound, etc. from a surface; **3.** [intransitive, transitive] to think carefully & deeply about something; **reflect well, badly, etc. on somebody/something** [idiom] to make somebody/something appear to be good, bad, etc. to other people.

<sup>426</sup>**approach** [n] **1.** [countable] a way of doing or thinking about something such as a problem or task; **2.** [singular] movement nearer to somebody/something in distance or time; **3.** [countable] **approach (to somebody/something)** the act of speaking to somebody about something, especially when making an offer or a request; **4.** [countable] a path, sea passage, etc. that leads to a particular place; **5.** [singular] **approach something** a thing that is like something else that is mentioned; [v] **1.** [transitive] to start dealing with a problem or task or considering a topic or situation in a particular way; **2.** [transitive] **approach something** to come close to something in quantity or quality; **3.** [intransitive, transitive] to move near to somebody/something in distance or time; **4.** [transitive] to speak to somebody about something, especially to offer to do something or to ask them for something.

of introductory<sup>427</sup> material<sup>428</sup>. Much of the presentation was technical. I would describe<sup>429</sup> a few “interesting” problems I had worked on & explain the methods I had used but would give little idea of context<sup>430</sup> because I really didn’t know what it was. For the seminar at hand, I prepared my usual hodgepodge<sup>431</sup> of this project & that, with no introduction<sup>432</sup>, no theme, & ultimately<sup>433</sup> no meaning to anyone but an expert<sup>434</sup>. Fortunately<sup>435</sup>, the professor supervising<sup>436</sup> my research, C., understood what was about to happen to me, & asked for a preview<sup>437</sup> of my seminar in his office<sup>438</sup>. Thank goodness<sup>439</sup> I accepted<sup>440</sup> this invitation<sup>441</sup>. C. expressed<sup>442</sup> surprise<sup>443</sup> at how poorly<sup>444</sup> I had prepared my talk (though I don’t think he was surprised at all), how little grasp I seemed to have of the reasons that the problems we had worked out were meaningful<sup>445</sup>, & consequently<sup>446</sup> how uninterestingly<sup>447</sup> I was going to present<sup>448</sup> them to my audience<sup>449</sup>. But, he told me, he thought I was too good technically to be allowed to fail in the way I was about to, & he gave me the lesson I needed.

His most important advice was:

<sup>427</sup>**introductory** [a] **1.** written or said at the beginning of something as an introduction to what follows, SYNONYM: **opening**; **2.** intended as an introduction to a subject or an activity for people who have never done it before; **3.** intended to persuade somebody to buy something for the 1st time.

<sup>428</sup>**material** [n] **1.** [countable, uncountable] a substance from which a thing is or can be made; a substance with a particular quality; **2.** [uncountable] information or ideas used in books or other work; **3.** [countable, usually plural, uncountable] things that are needed in order to do a particular activity, SYNONYM: **resource**; **4.** [uncountable, countable] cloth used for making clothes, etc., SYNONYM: **cloth, fabric**; [a] **1.** [only before noun] connected with money & possessions rather than with the needs of the mind or spirit, OPPOSITE: **spiritual**; **2.** [only before noun] connected with the physical world rather than with the mind or spirit, OPPOSITE: **spiritual**; **3.** important & needing to be considered. In law, **material** is used to describe evidence of facts that are important, especially when these facts might have an effect on the result of a case.

<sup>429</sup>**describe** [v] **1.** [often passive] to give an account of something in words. **Described** is often used after a noun phrase, without *that is/was*, etc.; **2.** [often passive] to say what somebody/something is like; to say what somebody/something is; **3.** **describe something** to make a movement which has a particular shape; to form a particular shape; **4.** **describe something** (*specialist*) (of a diagram or calculation) to represent something.

<sup>430</sup>**context** [n] [countable, uncountable] **1.** the situation or set of circumstances in which something happens & that helps you to understand it’ **2.** the words that come just before & after a word, phrase or statement & help you to understand its meaning.

<sup>431</sup>**hodgepodge** [n] (*North American English*) (also **hotchpotch** especially in *British English*) [singular] (*informal*) a number of things mixed together without any particular order or reason.

<sup>432</sup>**introduction** [n] **1.** [uncountable] the act of bringing something into use or operation for the 1st time; **2.** [countable] a thing that is brought into use or operation for the 1st time; **3.** [uncountable] **introduction of something (to/into something)** the act of bringing a plant, animal or disease to a place for the 1st time; **4.** [countable] a plant, animal or disease that is brought to a place for the 1st time; **5.** [uncountable] **introduction (of something)** the act of formally presenting a new law so that it can be discussed in a parliament; **6.** [countable] the 1st part of a book, report or speech that gives a general idea of what is to follow; **7.** [countable] **introduction (to something)** a book or course for people beginning to study a subject; **8.** [countable, uncountable] the act of making 1 person formally known to another, in which you tell each the other’s name; **9.** [singular] **introduction (to something)** a person’s 1st experience of a subject or thing; **10.** [countable] **introduction (to something)** a short section at the beginning of a piece of music.

<sup>433</sup>**ultimately** [adv] **1.** in the end; finally; **2.** at the most basic & important level, SYNONYM: **basically, essentially**.

<sup>434</sup>**expert** [n] a person with special knowledge, skill or training in something; [a] **1.** done or provided by somebody with special knowledge or skill in a particular area; **2.** having special knowledge, skill or training in something.

<sup>435</sup>**fortunately** [adv] by good luck, OPPOSITE: **unfortunately**.

<sup>436</sup>**supervise** [v] [transitive, intransitive] to be in charge of somebody/something & make sure that everything is done in a correct or safe way.

<sup>437</sup>**preview** [v] **preview something** to give a short account of something that is going to happen, be studied, etc.

<sup>438</sup>**office** [n] **1.** [countable] a room, set of rooms or building where people work; **2.** [countable] the local center of a large business; **3.** [uncountable, countable] an important position of authority, especially in government; the work & duties connected with this; **4.** (**Office**) [countable] used in the names of some British government departments; **5.** [countable] (*North American English*) = **surgery**.

<sup>439</sup>**goodness** [n] [uncountable] the quality of being good.

<sup>440</sup>**accept** [v] **1.** to take something that is offered; **2.** to believe or recognize that an idea is true or valid, OPPOSITE: **refuse**; **3.** to recognize that an unpleasant situation is real, OPPOSITE: **deny**; **4.** **accept something** to agree to or approve of a suggestion, plan or practice, OPPOSITE: **reject**; **5.** to make somebody/something welcome in a particular role; to allow somebody/something to join a group, OPPOSITE: **reject**; **6.** **accept something** to admit that you are responsible for something.

<sup>441</sup>**invitation** [n] **1.** [countable] a spoken or written request to somebody to do something or to go somewhere; **2.** [uncountable] the act of inviting somebody or of being invited; **3.** [countable, usually singular] something that encourages somebody to do something, usually something bad.

<sup>442</sup>**express** [v] **1.** to make a feeling or an opinion known by words, looks or actions; **2.** to speak, write or communicate in some other way what you think or feel; **3.** [often passive] (*mathematics*) to represent something in a particular way, e.g. by symbols; **4.** **express something** (+ **adv./prep.**) (*biochemistry*) (in plants & animals) to show a feature due to the presence of a gene; [a] [only before noun] **1.** (*formal*) (of a wish or an aim) clearly stated, SYNONYM: **definite, explicit**; **2.** done for a definite reason, SYNONYM: **specific**.

<sup>443</sup>**surprise** [n] **1.** [uncountable] a feeling caused by something happening suddenly or unexpected; **2.** [countable] an event, a piece of news, etc. that is unexpected or that happens suddenly; **3.** [uncountable] the use of methods that cause feelings of surprise; [v] to make somebody feel surprised.

<sup>444</sup>**poorly** [adv] in a way that is not good enough.

<sup>445</sup>**meaningful** [a] **1.** serious, useful or important; **2.** clearly showing the information that is required.

<sup>446</sup>**consequently** [adv] as a result, SYNONYM: **therefore**.

<sup>447</sup>**uninteresting** [a] not attracting your attention or interest; not interesting.

<sup>448</sup>**present** [a] **1.** [only before noun] existing or happening now, SYNONYM: **current**; **2.** [only before noun] (of a piece of work, etc.) being considered now; **3.** [not before noun] (of a thing or substance) existing in a particular place, group or situation, OPPOSITE: **absent**; **4.** [not before noun] (of a person) being in a particular place, OPPOSITE: **absent**; [n] **1.** (usually **the present**) [singular] the time now; **2.** a thing that you give to somebody as a gift; **3.** (**the present**) [singular] (*grammar*) = **present tense**; [v] **1.** [transitive] to show or offer information or ideas for other people to consider, SYNONYM: **provide**; **2.** [transitive] to show or describe somebody/something in a particular way; **3.** [transitive] to be the cause of a problem, difficulty or opportunity; **4.** [transitive] **present itself (to somebody)** (of an opportunity, an idea or a solution) to happen or become available; **5.** [transitive] to give something to somebody in a formal situation; **6.** [transitive] **present something** to produce a show, TV programme, etc. In British English, to **present** a show, etc. also means to introduce the items in it.; **7.** [intransitive] (*medical*) (of a condition or patient) to be seen.

<sup>449</sup>**audience** [n] **1.** [countable + singular or plural verb] the people who are watching or listening to a play, concert, somebody speaking, etc.;



1. There has to be a theme to your work – some objective<sup>450</sup> – something you want to know. There has to be a story<sup>451</sup> line<sup>452</sup>. (Do not start with, “I have been trying to explain the interesting wavelength<sup>453</sup> dependence<sup>454</sup> of light scattering<sup>455</sup> from small particles<sup>456</sup>,” but rather<sup>457 458</sup> “There is a widespread<sup>459</sup> need to explain to one’s kid why the sky is blue.”)
2. If you know why you have chosen to work on a particular<sup>460</sup> problem, it is easy to present an absorbing<sup>461</sup> seminar. Start out by telling your story, why the field you are working in is an important one, & what the main problems are. Give some historical<sup>462</sup> material showing where the field is, the relative<sup>463</sup> advantages<sup>464</sup> of different methods, & so on. Then outline<sup>465</sup> what you did, & describe your results. Conclude<sup>466</sup> with a statement<sup>467</sup> of how your results have

**2.** [countable] a number of people or a particular group of people who watch, read or listen to the same thing; **3.** [countable] **audience with somebody** a formal meeting with an important person.

<sup>450</sup>**objective** [n] **1.** something that you are trying to achieve, SYNONYM: **goal, target**; **2.** (also **objective lens specialist**) the lens in a telescope or microscope that is nearest to the object being looked at; [a] **1.** not influenced by personal feelings or opinions; considering only facts, SYNONYM: **impartial, unbiased**; **2.** (*philosophy*) existing outside the mind; based on facts that can be proved.

<sup>451</sup>**story** [n] (plural **stories**) **1.** **story (about/of something/somebody)** a description, often spoken, of what happened to somebody or of how something happened; **2.** a situation considered in terms of the information that is known about it; **3.** a description of events & people that the writer or speaker has invented in order to entertain people; **4.** a report in a newspaper, magazine or news broadcast; **5.** (also **storyline**) the series of events in something such as a book, film or play, SYNONYM: **plot**.

<sup>452</sup>**storyline** [n] the basic story in a novel, play, film, etc., SYNONYM: **plot**.

<sup>453</sup>**wavelength** [n] the distance between 2 similar points in a wave, especially points in a sound wave or electromagnetic wave, such as light.

<sup>454</sup>**dependence** [n] [uncountable] **1.** the state of needing somebody/something in order to survive or be successful; **2.** (also **dependency**) the state of being addicted to something; **3. dependence of A & B** the fact of 1 thing being affected by another.

<sup>455</sup>**scatter** [v] **1.** [intransitive, transitive] (*physics*) to change direction or spread in many directions; to make something change direction or spread in many directions; **2.** [transitive, often passive] **scatter something (on/over/around something)** to throw or drop things in different directions so that they cover an area; **3.** [transitive, often passive] to be found spread over an area rather than all together; **4.** [intransitive, transitive] (of people or animals) to move very quickly in different directions; to make people or animals do this, SYNONYM: **disperse**; [n] (also **scattering**) [singular] **scatter (of something)** a small amount of something or a small number of people or things spread over an area.

<sup>456</sup>**particle** [n] **1.** (also **elementary particle, subatomic particle physics**) a very small piece of matter, such as an electron or proton; **2.** a very small piece of something; **3.** (*grammar*) an adverb or a preposition that can combine with a verb to make a phrasal verb.

<sup>457</sup>**rather** [adv] **1.** used to mean ‘fairly’ or ‘to some degree’, often when expressing slight criticism or surprise; **2.** used to correct something you have said, or to give more accurate information; **3.** used to introduce an idea that is different or opposite to the idea that you have stated previously; **would rather ... (than ...)** [idiom] would prefer to.

<sup>458</sup>**rather than** [prep] instead of somebody/something.

<sup>459</sup>**widespread** [a] existing or happening over a large area or among many people, SYNONYM: **extensive**.

<sup>460</sup>**particular** [a] [only before noun] **1.** used to emphasize that you are referring to 1 individual person, thing or type of thing & not others, SYNONYM: **specific**; **2.** greater than usual; special; **in particular** [idiom] **1.** especially or particularly; **2.** special, SYNONYM: **specific**; **of particular note** [idiom] especially interesting; [n] **1.** [countable, usually plural] a fact or detail, especially one that is officially written down; **2.** (**particulars**) [plural] written information & details about a property, business, job, etc.

<sup>461</sup>**absorb** [v] **1.** to take in a liquid, gas or other substance from the surface or space around; **2. absorb something** to take in & keep heat, light or other forms of energy, instead of reflecting it; **3.** [often passive] to take control of a smaller unit or group & make it part of something larger; **4.** to take something into the mind & learn or understand it, SYNONYM: **take something in**; **5. absorb something** to deal with or reduce the effects of changes or costs; **6. absorb something** to use up a large supply of something, especially money or time; **7. be absorbed in something** to be so interested in something that you pay no attention to anything else.

<sup>462</sup>**historical** [a] [usually before noun] **1.** connected with the past; **2.** connected with the study of history; **3.** (of a book or film) about people & events in the past.

<sup>463</sup>**relative** [a] **1.** considered & judged by being compared with something else; **2.** [only before noun] existing or having a particular quality only when compared with something else, SYNONYM: **comparative**; **3.** (*grammar*) referring to an earlier noun, sentence or part of a sentence; **relative to somebody/something** [idiom] **1.** in comparison with somebody/something; **2.** in relation to somebody/something; **3.** about or concerning somebody/something; [n] **1.** a person who is in the same family as somebody else, SYNONYM: **relation**; **2.** a type of animal or plant that belongs to the same group as something else.

<sup>464</sup>**advantage** [n] [countable, uncountable] **1.** a thing that helps you to be better or more successful than other people, OPPOSITE: **disadvantage**; **2.** a quality of something that makes it better or more useful, OPPOSITE: **disadvantage**; [v] [usually passive] **advantage somebody (over somebody)** to put somebody in a better position than other people or than they were in before.

<sup>465</sup>**outline** [v] **1.** to give a description of the main facts or points involved in something, SYNONYM: **sketch**; **2.** [usually passive] **be outlined (+ adv./prep.)** to show or mark the outer edge of something; [n] [countable, uncountable] **1.** a description of the main facts or points involved in something; **2.** the line that goes around the edge of something, showing its main shape but not the details.

<sup>466</sup>**conclude** [v] **1.** [transitive] (not used in the progressive tenses) to decide or believe something as a result of what you have heard or seen; **2.** [intransitive, transitive] to come to an end; to bring something to an end; **3.** [transitive] (*formal*) to arrange or agree something with somebody formally & finally.

<sup>467</sup>**statement** [n] **1.** [countable] something that you say or write that gives information or an opinion; **2.** [countable] a formal or official account of facts, opinions or plans, especially one that appears in the newspapers, on television, etc., SYNONYM: **declaration, announcement**; **3.** [countable] a formal account of facts or events that is given by a witness or other person to the police or in a court; **4.** [countable] a printed record of money paid, received, etc.; **5.** [uncountable] (*formal*) the act of stating or expressing something in words, SYNONYM: **expression**; **make a statement** [idiom] to express or show an opinion or characteristic in a very clear way, although often without words.

advanced<sup>468</sup> our understanding of nature, & perhaps give an inkling<sup>469</sup> of the new directions<sup>470</sup> that your work opens up. Do not assume<sup>471</sup> that your audience comprises<sup>472</sup> experts<sup>473</sup> only. There may be a couple<sup>474</sup> of them, but even experts like to hear things that they understand & particularly<sup>475</sup> to have their colleagues<sup>476</sup> hear (from someone else) why their field is an important one.

3. Lastly<sup>477</sup>, rehearse<sup>478</sup> your talk in front of 1 or 2 of your peers<sup>479</sup> or professional supporters<sup>480</sup>. Choose listeners<sup>481</sup> who will not be shy<sup>482</sup> about asking questions<sup>483</sup> & offering<sup>484 485</sup> constructive<sup>486</sup> suggestions<sup>487</sup>. Giving a seminar is

<sup>468</sup>**advance** [n] **1.** [countable, uncountable] **advance (in something)** progress or a development in a particular activity or area of understanding; **2.** [countable, uncountable] **advance (on something)** a forward movement of something across an area; **3.** [countable] **advance (for something)** money paid for work before it has been done; money paid earlier than expected; **4.** [countable] an increase in the price, value or amount of something; **in advance (of something)** [idiom] **1.** before something happens; **2.** more developed than somebody/something else; [v] **1.** [intransitive] to move forward towards somebody/something or across an area; **2.** [intransitive, transitive] (of knowledge, technology, etc.) to develop & make progress; to cause knowledge, technology, etc. to develop & make progress; **3.** [transitive] **advance something** to help something to succeed or improve, SYNONYM: **further**; **4.** [transitive] **advance something** to suggest an idea, a theory or a plan for other people to discuss, SYNONYM: **put something forward**; **5.** [transitive] to give somebody money before something happens or before the time it would usually be paid; **6.** [transitive] **advance something** to change the time or date of an event so that it takes place earlier, OPPOSITE: **postpone**; **7.** [intransitive, transitive] to continue forward to a later part of something; to move something forward to a later part; [a] [only before noun] done, sent or given before something is going to happen.

<sup>469</sup>**inkling** [n] [usually singular] a slight knowledge of something that is happening or about to happen, SYNONYM: **suspicion**.

<sup>470</sup>**direction** [n] **1.** [countable, uncountable] the general position that somebody/something moves or points towards; **2.** [countable, uncountable] the general way in which somebody/something develops; **3.** [countable] the general position a person or thing comes or develops from; **4.** [uncountable] a purpose; an aim; **5. (directions)** [plural] instructions on how to do something or how to reach a place; **6.** [uncountable] the art of managing or guiding somebody/something; **put in different/opposite directions** [idiom] to have different aims that cannot be achieved together without causing problems.

<sup>471</sup>**assume** [v] **1.** to think or accept that something is true but without having proof of it; **2. assume something** to begin to have a particular quality, appearance or importance; **3. assume something** to take or begin to have power or responsibility, SYNONYM: **take**.

<sup>472</sup>**comprise** [v] (not used in the progressive tenses) **1. (also be comprised of)** to have somebody/something as parts or members, SYNONYM: **be composed of something, consist of somebody/something**; **2. comprise something** to be the parts or members that form something, SYNONYM: **make something up**.

<sup>473</sup>**expert** [n] a person with special knowledge, skill or training in something; [a] **1.** done or provided by somebody with special knowledge or skill in a particular area; **2.** having special knowledge, skill or training in something.

<sup>474</sup>**couple** [n] In *British English* a plural verb is usually used in both meanings. **1.** [countable + singular or plural verb] 2 people who are married or in a romantic or sexual relationship; **2.** [singular + singular or plural verb] **couple of something** 2 or approximately 2 things or people of the same sort; [v] [usually passive] to link together 2 or more things or parts of something.

<sup>475</sup>**particularly** [adv] especially; more than usual or more than others.

<sup>476</sup>**colleague** [n] a person that you work with, especially in a profession or business.

<sup>477</sup>**lastly** [adv] **1.** used to introduce the final point that you want to make, SYNONYM: **finally**; **2.** at the end; after all the other things that you have mentioned.

<sup>478</sup>**rehearse** [v] **1.** [intransitive, transitive] to practice or make people practice a play, piece of music, etc. in preparation for a public performance; **2.** [transitive] to prepare in your mind or practice privately what you are going to do or say to somebody; **3.** [transitive] **rehearse something** (*formal, usually disapproving*) to repeat ideas or opinions that have often been expressed before.

<sup>479</sup>**peer** [n] **1.** [usually plural] a person who is the same age or who has the same social status as you; **2.** (in Britain) a member of the nobility.

<sup>480</sup>**supporter** [n] **supporter (of somebody/something)** a person who supports a political party, an idea, etc.

<sup>481</sup>**listener** [n] **1.** a person who listens; **2.** a person listening to a radio programme.

<sup>482</sup>**shy** [a] (**shyer, shyest**) **1.** (of people) nervous or embarrassed about meeting & speaking to other people; **2.** [not before noun] afraid of doing something or being involved in something; **3. (-shy)** (in compounds) avoiding or not liking the thing mentioned.

<sup>483</sup>**question** [n] **1.** [countable] a sentence, phrase or word that asks for information; **2.** [countable] a matter or topic that needs to be discussed or dealt with; **3.** [uncountable, countable] doubt or confusion about something; **4.** [countable] a task or request for information that is intended to test your knowledge or understanding, e.g. in an exam or a competition; **question** [v] **1.** to have or express doubts about something, SYNONYM: **challenge**; **2.** to ask somebody questions about something, especially officially.

<sup>484</sup>**offer** [v] **1.** [transitive] to give or provide something; **2.** [transitive] to say that you are willing to give something to somebody or to do something for somebody; **have something to offer** [idiom] to have something available that somebody wants; [n] **1.** an act of saying that you are willing to do something for somebody or give something to somebody; **2. offer (of something)** an amount of money that somebody is willing to pay for something; **3.** a reduction in the normal price of something, usually for a short period of time; **on offer** [idiom] that can be bought, used, etc.

<sup>485</sup>**offering** [n] **1.** something that is produced for other people to use, watch, enjoy, etc.; **2.** something that is given to a god as part of religious worship.

<sup>486</sup>**constructive** [a] having a useful & helpful effect rather than being negative or with no purpose.

<sup>487</sup>**suggestion** [n] **1.** [countable] an idea or a plan that you put forward for somebody else to consider; **2.** [uncountable, countable, usually singular] a reason to think that something is true, SYNONYM: **hint**; **3.** [countable, usually singular] **suggestion (of something)** a slight amount or sign of something, SYNONYM: **hint, trace**; **4.** [uncountable] the action of putting an idea into people's minds by connecting it with other ideas; **at/on somebody's suggestion** [idiom] because somebody suggested it.



serious<sup>488</sup> business. Your future<sup>489</sup> depends on the strong recommendations<sup>490</sup> of your senior colleagues<sup>491</sup>. If your talk is a hodgepodge of techniques or experiments or equations<sup>492</sup>, if you seem to have no idea where you are headed, if you reek<sup>493</sup> of deference<sup>494</sup> to the experts in the audience, you will not be perceived<sup>495 496</sup> as a rising star, a budding<sup>497</sup> scientific leader<sup>498</sup>. You will fail.

The wonderful result of C.'s mentoring was that I finally learned what it means to be a scientist. In making my work meaningful to others, I had also made it compelling<sup>499</sup> to myself. No longer was I just working on somebody else's problems. I was part of an intellectual<sup>500</sup> enterprise<sup>501</sup> with relatively<sup>502</sup> well-defined<sup>503</sup> goals<sup>504</sup>, which might actually<sup>505</sup> make a difference<sup>506</sup> to humanity<sup>507</sup>. I scrapped<sup>508</sup> most of the equations I had planned to show & refocused<sup>509</sup> my talk using thematic<sup>510</sup> material I had garnered<sup>511</sup> from C. I gave an excellent<sup>512</sup> seminar – people I scarcely<sup>513</sup> knew complimented<sup>514</sup>

<sup>488</sup>**serious** [a] **1.** important & worrying because of possible danger or risk; **2.** that must be treated as important & thought about carefully; **3.** thinking about things in a careful & sensible way; **4.** **serious about (doing) something** sincere about something.

<sup>489</sup>**future** [a] [only before noun] **1.** taking place or existing at a time after the present; **2.** (of a person) planned or intended to hold the position mentioned; **3.** (*gramamr*) expressing an event that has not yet happened; [n] **1.** **(the future)** [singular] the time that will come after the present; **2.** **(the future)** [singular] events that will or are likely to happen in time to come; **3.** [countable] what will happen to somebody/something in time to come; **4.** [singular] the possibility of being successful or surviving at a later time; **5.** **(futures)** [plural] (*finance*) contracts for goods or shares that are bought at agreed prices but that will be delivered & paid for later; **6.** **(the future)** (also **the future tense**) [singular] the form of a verb that expresses events that have not yet happened; **for/in the foreseeable future** [idiom] for/in the period of time when you can predict what is going to happen, based on the present circumstances; **in future** (*British English*) [idiom] (*North American English in the future*) from now on.

<sup>490</sup>**recommendation** [n] an official suggestion about the best thing to do.

<sup>491</sup>**colleague** [n] a person that you work with, especially in a profession or business.

<sup>492</sup>**equation** [n] **1.** [countable] (*mathematics*) a statement showing that 2 amounts or values are equal; **2.** [countable] (*chemistry*) a statement using symbols to show the changes that happen in a chemical reaction; **3.** [uncountable, singular] the act of making something equal or considering something as equal; **4.** [countable, usually singular] a situation in which several factors must be considered & dealt with.

<sup>493</sup>**reek** [v] **1.** [intransitive] **reek (of something)** to smell very strongly of something unpleasant; **2.** [intransitive] **reek (of something)** (*disapproving*) to make you think that something unpleasant, wrong or dishonest is involved in a situation; [n] [singular] a strong unpleasant smell, SYNONYM: **stench**.

<sup>494</sup>**deference** [n] [uncountable] behavior that shows respect for somebody/something.

<sup>495</sup>**perceive** [v] **1.** to notice or become aware of something, SYNONYM: **notice**; **2.** to be aware of or experience something using the senses; **3.** [often passive] to understand or think of somebody/something in a particular way; to believe that a particular thing is true, SYNONYM: **see**.

<sup>496</sup>**perceived** [a] as understood or believed by a particular person or group.

<sup>497</sup>**budding** [a] [only before noun] beginning to develop or become successful.

<sup>498</sup>**leader** [n] **1.** **leader (of something)** a person who leads a group of people, especially the head of a country or an organization; **2.** an organization, a country or a person that is the most advanced or successful in a particular area.

<sup>499</sup>**compelling** [a] **1.** that makes you think it is true or valid; **2.** making you pay attention through being so interesting & exciting; **3.** that cannot be resisted.

<sup>500</sup>**intellectual** [a] [usually before noun] connected with or using a person's ability to think in a logical way & understand things, SYNONYM: **mental**; [n] a person who is well educated & enjoys activities in which they have to think seriously about things.

<sup>501</sup>**enterprise** [n] **1.** [countable] a company or business; **2.** [countable, uncountable] a project or attempt, especially one that is difficult, SYNONYM: **venture**; **3.** [uncountable] the development of businesses by the people of a country rather than by the government; **4.** [uncountable] the ability to think of new projects & make them successful, SYNONYM: **initiative**.

<sup>502</sup>**relatively** [adv] to a fairly large degree, especially in comparison with something else; **relatively speaking** [idiom] used when you are comparing something with all similar things.

<sup>503</sup>**well defined** [a] easy to see or understand.

<sup>504</sup>**goal** [n] something that you hope to achieve, SYNONYM: **aim**.

<sup>505</sup>**actually** [adv] **1.** used to emphasize a fact or the truth about a situation; **2.** used to show a contrast between what is true & what somebody believes, & to show surprise about this contrast.

<sup>506</sup>**difference** [n] **1.** [countable, uncountable] the way in which 2 people or things are not like each other; the state of being different; **2.** [uncountable, countable, usually singular] the amount by which something is greater or smaller than something else; **3.** [countable] a disagreement between people, SYNONYM: **disagreement**; **make a, no, some, etc. difference (to/in somebody/something)** [idiom] to have an effect/no effect on somebody/something; **a world of difference (between A & B)** [idiom] used to emphasize how much difference there is between 2 people or things.

<sup>507</sup>**humanity** [n] **1.** [uncountable] people in general; **2.** [uncountable] **humanity (of somebody)** the state of being a person rather than a god, an animal or a machine; **3.** [uncountable] the quality of being kind to people & animals by making sure that they do not suffer more than is necessary; the quality of being humane; **4.** **((the) humanities)** [plural] the subjects of study that are concerned with human culture, especially literature, history, art, music & philosophy.

<sup>508</sup>**scrap** [v] **1.** [transitive, often passive] **scrap something** to cancel or get rid of something that is no longer practical or useful; **2.** [intransitive] (*informal*) to fight with somebody.

<sup>509</sup>**refocus** [v] **1.** [intransitive, transitive] to give attention, effort, etc. to something new or different; **2.** [intransitive, transitive] (of your eyes, a camera, etc.) to adapt or be changed again so that things can be seen clearly; to change something again so that you can see things clearly.

<sup>510</sup>**thematic** [a] [usually before noun] connected with the theme or themes of something.

<sup>511</sup>**garner** [v] (*formal*) **garner something** to obtain or collect something such as information, support, etc., SYNONYM: **gather**, **acquire**.

<sup>512</sup>**excellent** [a] extremely good.

<sup>513</sup>**scarcely** [adv] only just; almost not, SYNONYM: **hardly**.

<sup>514</sup>**compliment** [v] **compliment somebody (on something)** to tell somebody that you like or admire.

me afterward<sup>515</sup> on my choice of an exciting<sup>516</sup> research area & remarked<sup>517</sup> on the clarity<sup>518</sup> of my presentation. In science, the reinforcement<sup>519</sup> doesn't get much more positive<sup>520</sup> than that. I had learned a key lesson & was on my way." – Feibelman, 2011, pp. 2–6

## 1.1.2 Timing Is Everything

"Having completed a respectable<sup>521</sup> thesis problem & having acquired<sup>522</sup> a reputation<sup>523</sup> in graduate school as an excellent sounding<sup>524</sup> board<sup>525</sup> & scientific consultant<sup>526</sup>, T. accepted a postdoctoral position with a leading scientist at a 1st-rate<sup>527</sup> government laboratory<sup>528</sup>. There, he was offered & began to work on a computational<sup>529</sup> research project that 1st involved arriving at a numerically<sup>530</sup> practical<sup>531</sup> mathematical formulation<sup>532</sup> of a problem & then required a considerable<sup>533</sup> com-

<sup>515</sup>**afterwards** [adv] (*especially British English*) (*North American English usually afterward*) at a later time; after an event that has already been mentioned.

<sup>516</sup>**exciting** [a] causing great interest or excitement.

<sup>517</sup>**remark** [n] something that you say or write that expresses an opinion or a thought about somebody/something, SYNONYM: **comment**; [v] [intransitive, transitive] to say or write a comment about something/somebody, SYNONYM: **comment**.

<sup>518</sup>**clarity** [n] [uncountable] **1.** the quality of being expressed clearly; **2.** the quality to think about or understand something clearly; **3.** if a picture, substance or sound has clarity, you can see or hear it very clearly, or see through it easily.

<sup>519</sup>**reinforcement** [n] **1.** (**reinforcements**) [plural] extra soldiers or police officers who are sent to a place because more are needed; **2.** [uncountable, singular] the act of making a feeling, idea, habit or tendency stronger; **3.** [uncountable] the act of making a structure or material stronger, especially by adding another material to it.

<sup>520</sup>**positive** [a] **1.** good or useful, OPPOSITE: **negative**; **2.** noticing or emphasizing what is good in somebody/something; showing confidence or hope, OPPOSITE: **negative**; **3.** expressing agreement, support or permission, OPPOSITE: **negative**; **4.** aimed at dealing with something; taking action to produce a particular result, SYNONYM: **negative**; **5.** giving clear or definite proof or information, OPPOSITE: **negative**; **6.** (of a scientific test) showing that a substance or medical condition is present, or that a particular event has happened, OPPOSITE: **negative**; **7.** (of a number or value) > 0, OPPOSITE: **negative**; **8.** (of a relationship between 2 amounts or events) related in such a way that, when one increases, the other also increases, OPPOSITE: **negative**; **9.** containing or producing the type of electricity that is carried by a proton, OPPOSITE: **negative**; [n] **1.** the result of a test or an experiment that shows that a substance or condition is present, OPPOSITE: **negative**; **2.** a good or useful quality or aspect; the aspects of a situation that are good or useful, OPPOSITE: **negative**.

<sup>521</sup>**respectable** [a] **1.** considered by society to be acceptable, good or correct; **2.** acceptable in number, size or amount.

<sup>522</sup>**acquire** [v] **1.** **acquire something** to learn to develop a skill, habit or quality; **2.** **acquire something** to obtain something by buying or being given it; **3.** **acquire something** to come to have a particular reputation.

<sup>523</sup>**reputation** [n] the opinion that people have about what somebody/something is like, based on what has happened in the past.

<sup>524</sup>**sound** [n] **1.** [countable] something that can be heard; **2.** [uncountable] continuous movements (called vibrations) that travel through air or water & can be heard when they reach a person's or an animal's ear; **3.** [uncountable] what you can hear coming from a television, radio, etc., or as part of a film; [v] (not usually used in the progressive tenses) **1.** *linking verb* to give a particular impression when heard or read about. In spoken English, people often use **like** instead of **as if** or **as though** in this meaning. This is not correct in academic English. **Like** can be used before a noun phrase but not before a clause.; **2.** (**-sounding**) (in adjectives) giving the impression of being something; **3.** [intransitive, transitive] to give a signal such as a warning by making a sound; **4.** [transitive] to express a particular opinion about a situation or idea; [a] (**sounder, soundest**) **1.** sensible; that can be relied on & that will probably give good results; **2.** in good condition; not damaged or hurt; **3.** [only before noun] good & thorough.

<sup>525</sup>**board** [n] **1.** [countable + singular or plural verb] **board (of somebody/something)** a group of people who have power to make decisions & control a company or other organization; **2.** [countable] used in the name of some organizations; **3.** [countable] a vertical surface on which to write or attach notices; **4.** [countable] a thin, flat piece of wood or other stiff material on which to cut things, play games or perform other activities; **5.** [countable, uncountable] a long thin piece of strong hard material, especially wood, used, e.g., for making floors, building walls & roofs, & making boats; **6.** [uncountable] the meals that are provided when you stay in a place such as a hotel; **across the board** [idiom] involving or applying to everyone or everything.

<sup>526</sup>**consultant** [n] **1.** a person who has a lot of knowledge about a particular subject & is employed to give advice about it to other people; **2.** (*British English*) a hospital doctor of the highest rank who is a specialist in a particular area of medicine.

<sup>527</sup>**1st-rate** [a] of the highest quality, SYNONYM: **excellent**.

<sup>528</sup>**laboratory** [n] (plural **laboratories**) (also *informal lab*) a room or building containing equipment for scientific experiments, research or teaching, or for making drugs or chemicals.

<sup>529</sup>**computational** [a] [usually before noun] using or connected with computers.

<sup>530</sup>**numerically** [adv] in a way that is expressed in numbers or is connected with numbers.

<sup>531</sup>**practical** [a] **1.** connected with real situations rather than with ideas or theories; **2.** (of an idea, a method or a course of action) right or sensible; possible & likely to be successful, SYNONYM: **feasible**, **workable**, OPPOSITE: **impractical**; **3.** (of things) useful or suitable for a particular purpose, OPPOSITE: **impractical**; **4.** (of a person) sensible & realistic in the way they approach a problem or situation; **for (all) practical purposes** [idiom] used to say that something is so nearly true that it can be considered to be so; [n] (*British English, informal*) a lesson or an exam in science or technology in which students have to do or make things, not just read or write about them.

<sup>532</sup>**formulation** [n] **1.** [uncountable, countable] the act of creating or preparing something carefully, giving particular attention to the details; something that has been created in this way; **2.** [countable] a medical drug that has been prepared in a particular way.

<sup>533</sup>**considerable** [a] great in amount, size or importance.

puter<sup>534</sup> programming<sup>535</sup> effort<sup>536</sup>. As the months passed, & with the necessity<sup>537</sup> on the horizon<sup>538</sup> of finding a permanent job, T. absorbed<sup>539</sup> himself totally<sup>540</sup> in his very challenging<sup>541</sup> work. Whereas in graduate school, under little time pressure<sup>542</sup>, he would have spent a few hours each week visiting labs & contributing<sup>543</sup> to projects other than his own, as a postdoc, T. became utterly<sup>544</sup> single-minded<sup>545</sup>.

Working 12 hours a day & more, he managed to complete his computer program soon enough to be able to run test<sup>546</sup> calculations<sup>547</sup>. The results were promising<sup>548</sup> but not far enough along to yield<sup>549</sup> a persuasive<sup>550</sup> “story.” Accordingly<sup>551</sup>,

<sup>534</sup>**computer** [n] an electronic machine that can store, organize & find data, do calculations & control other machines.

<sup>535</sup>**programming** [n] [uncountable] **1.** the process of writing & testing programs for computers; **2. programming (of something)** the activity of planning which television or radio programmes to broadcast; the programmes that are broadcast; **3.** factors, ranging from genetic to social, that instruct a person or animal to behave in a certain way.

<sup>536</sup>**effort** [n] **1.** [uncountable, countable] the physical or mental energy that you need to do something; something that takes a lot of energy; **2.** [countable] an attempt to do something, especially when it is difficult to do; **3.** [countable] (usually after a noun) a particular activity that a group of people organizes in order to achieve something.

<sup>537</sup>**necessity** [n] **1.** [uncountable] the fact that something must happen or be done; the need for something; **2.** [countable] **necessity (of something)** a thing that you must have & cannot manage without; **3.** [countable, usually singular] a situation that must happen & that cannot be avoided.

<sup>538</sup>**horizon** [n] **1. (the horizon)** [singular] the line at which the earth’s surface & the sky appear to meet; **2.** [countable, usually plural] the limit of your experience, knowledge or interests; **3. (earth sciences)** a layer of soil or rock with particular characteristics; **on the horizon** [idiom] likely to happen soon.

<sup>539</sup>**absorb** [v] **1.** to take in a liquid, gas or other substance from the surface or space around; **2. absorb something** to take in & keep heat, light or other forms of energy, instead of reflecting it; **3.** [often passive] to take control of a smaller unit or group & make it part of something larger; **4.** to take something into the mind & learn or understand it, SYNONYM: **take something in**; **5. absorb something** to deal with or reduce the effects of changes or costs; **6. absorb something** to use up a large supply of something, especially money or time; **7. be absorbed in something** to be so interested in something that you pay no attention to anything else.

<sup>540</sup>**totally** [adv] (used to emphasize the following word or phrase) completely.

<sup>541</sup>**challenging** [a] difficult in an interesting way that tests your ability.

<sup>542</sup>**pressure** [n] [countable, uncountable] **1.** the force with which somebody/something presses against something; **2. (specialist)** the force produced by a solid, liquid or gas on a particular area, e.g. when pressing against a surface or when in or leaving a closed space; **3.** the force of the atmosphere on the earth’s surface; **4. (medical)** the force with which blood travels around the body, SYNONYM: **blood pressure**; **5.** the feeling that it is necessary to do something; the action of making somebody feel this; the problems caused by this; [v] [often passive] (*disapproving*) to try to persuade somebody to do something, especially by making them feel that they must or should do it.

<sup>543</sup>**contribute** [v] **1.** [intransitive] **contribute (to something)** to be 1 of the causes of something; **2.** [intransitive, transitive] to help to improve or achieve something, especially by adding new ideas; **3.** [transitive, intransitive] to give something, especially money or goods, to help somebody/something; **4.** [transitive, intransitive] to write something for a newspaper, magazine, website, or a radio or television programme; to speak during a meeting or conversation, especially to give your opinion.

<sup>544</sup>**utterly** [adv] (used for emphasis) completely.

<sup>545</sup>**single-minded** [a] only thinking about 1 particular aim goal because you are determined to achieve something.

<sup>546</sup>**test** [n] **1.** a procedure to discover how good or reliable something is, or to find out more information about it. In chemistry, a **test** may be used to identify a substance or to find out if a particular chemical is present in a substance; **2.** a medical examination to discover if somebody has a particular illness or condition. Medical **tests** are usually done by taking samples of body tissues or fluids, rather than by physically examining a patient’s body. When a doctor examines a person’s body, it is called an **examination**.; **3.** an examination of somebody’s knowledge for ability, consisting of questions for them to answer or activities for them to perform; **4. test of something** a situation, event or activity that shows how good, strong, etc. somebody/something is; **5.** a way of proving or deciding whether an action or situation is an example of a particular quality. In law, a **test case** is a legal case who result will be used as an example when decisions are being made on similar cases in the future. However, the term is also used in other disciplines to mean a situation whose result may help you predict the results of similar situations; **put somebody/something to the test** [idiom] to put somebody/something in a situation which will show what their/its true qualities are; **stand the test of time** [idiom] to prove to be good, popular, etc. over a long period of time; [v] **1.** [transitive, intransitive] to do something to check how good or reliable something is or to find out more information about it. In chemistry, to **test** a substance is to examine a substance using a reagent, especially in order to find out if another chemical is present.; **2.** [transitive] to examine the blood, a part of the body, etc. to find out what is wrong with a person, or to check the condition of their health; **3.** [intransitive] **test positive/negative (for something)** to produce a particular result in a medical test, especially a drugs test or HIV test; **4.** [transitive] to find out how much somebody knows or what they can do by asking them questions or giving them activities to perform; **5.** [transitive] **test somebody/something** to be difficult & therefore need all your strength, ability, etc.; **tried & tested/trusted** [idiom] (*British English*) (*North American English tried & true*) that you have used or relied on in the past successfully.

<sup>547</sup>**calculation** [n] [countable, uncountable] **1.** the act or process of using numbers to find out an amount; **2.** the process of using your judgment to decide what the results would be of doing something.

<sup>548</sup>**promising** [a] showing signs of future success.

<sup>549</sup>**yield** [v] **1.** [transitive] **yield something** to produce or provide something, e.g. a result, information or a profit; **2.** [intransitive] to stop resisting something/somebody; to agree to do something that you do not want to do, SYNONYM: **give way to something**; **3.** [transitive] **yield something/somebody (to somebody)** to allow somebody to win, have or take control of something that has been yours until now, SYNONYM: **surrender**; [n] [countable, uncountable] the total amount of something that is grown or produced.

<sup>550</sup>**persuasive** [a] able to persuade somebody to do or believe something.

<sup>551</sup>**accordingly** [adv] **1.** in a way that is appropriate to what has been done or said in a particular situation; **2.** (used especially at the beginning of a sentence) for that reason, SYNONYM: **therefore**.

neither<sup>552</sup> T. nor<sup>553</sup> his audiences found his job seminar very exciting<sup>554</sup>. What is more, since he had not taken time to meet & consult<sup>555</sup> with scientists at his lab<sup>556</sup>, his only strong recommendation was from his postdoctoral adviser. The lab itself was unwilling<sup>557</sup> to promote<sup>558</sup> T. to a permanent position, which it sometimes did, because he had not made himself useful<sup>559</sup>, or even known<sup>560</sup>, to a spectrum<sup>561</sup> of its staff<sup>562</sup> members<sup>563</sup>.

On the outside<sup>564</sup>, his job offers were a cut below what his thesis adviser had expected<sup>565</sup> for him. In the competition for the best positions, T. did not persuade potential employers that he would ever derive useful results from his postdoctoral project, even though T.

” – Feibelman, 2011, pp. 6–

## 1.2 Advice from a Dinosaur?

“Can you expect someone to be an effective mentor who emerged into the scientific marketplace in a world that looked very different?”

## 1.3 Important Choices: A Thesis Adviser, a Postdoctoral Job

“A discussion of what to consider: young adviser versus an older one, a superstar versus a journeyman, a small group versus a “factory.” Understanding & attending to *your* interests as a postdoc.”

## 1.4 Giving Talks

“Preparing talks that will make people want to hire & keep you & that will make the information you present easy to assimilate.”

## 1.5 Writing Papers: Publishing Without Perishing

“Why it is important to write good papers. When to write up your work, how to draw the reader in, how to draw attention to your results.”

<sup>552</sup>**neither** [determine, pronoun] not 1 nor other of 2 things or people; not either; [adv] **1.** used to show that a negative statement is also true of somebody/something else; **2.** (**neither ... nor ...**) used to show that a negative statement is true of 2 things.

<sup>553</sup>**nor** [conjunction, adv] & not.

<sup>554</sup>**exciting** [a] causing great interest or excitement.

<sup>555</sup>**consult** [v] **1.** [transitive, intransitive] to discuss something with somebody to get their permission for something, or to help you make a decision; **2.** [transitive, intransitive] to go to somebody for information or advice, especially an expert such as a doctor or lawyer; **3.** [transitive] **consult something** to look in or at something to get information, SYNONYM: **refer to something**.

<sup>556</sup>**lab** [n] (*informal*) = **laboratory**.

<sup>557</sup>**unwilling** [a] **1.** [not usually before noun] not wanting to do something & refusing to do it, OPPOSITE: **willing**; **2.** [only before noun] not wanting to do or be something, but forced to by other people, SYNONYM: **reluctant**, OPPOSITE: **willing**.

<sup>558</sup>**promote** [v] **1. promote something** to help something to happen or develop, SYNONYM: **encourage**; **2.** to help sell a product or service or make it more popular by advertising it or offering it at a special price; **3.** [often passive] to move somebody to a higher rank or more senior job.

<sup>559</sup>**useful** [a] helping somebody/something to do or achieve something.

<sup>560</sup>**known** [a] known about, especially by a lot of people; = past participle of **know**.

<sup>561</sup>**spectrum** [n] (plural **spectra**) **1.** a pattern of colored bands formed when light is split into its constituent wavelengths, as seen, e.g., in a rainbow; **2.** (*physics*) any signal ordered by 1 of its properties, such as its energy or mass; **3.** [usually singular] a complete or wide range of people or things.

<sup>562</sup>**staff** [n] **1.** [plural] (*British English*) all the workers employed in an organization considered as a group. In this meaning, **staff** is plural & takes a plural verb; it is the most common meaning in British English but is not used in American English. You can sometimes use **staff members** instead.; **2.** [countable] **staff (of somebody)** a group of workers employed by an organization or a particular person. In this meaning, **staff** is singular & the plural is **staffs**; it is used in both British & American English.; **3.** [plural] (*British English*) the teachers in a school or college. In American English, **the staff** is the people who work at a school or college, but who do not teach students: *students, faculty & staff*.; **4.** [countable + singular or plural verb] a group of senior army officers who help the officer who is in charge of a military unit; [v] [transitive, often passive] to work in an organization; to provide people to work in an organization.

<sup>563</sup>**member** [n] **1.** a person, country or organization that has joined a particular group, club or team; **2.** a person, an animal or a plant that belongs to a particular group; **3.** (**Member (for something)**) (in Britain) a Member of Parliament.

<sup>564</sup>**outside** [n] **1.** (usually **the outside**) [countable, usually singular] the outer side or surface of something, SYNONYM: **exterior**, OPPOSITE: **inside**; **2.** [singular] the area that is near or around something; **3.** (usually **the outside**) [singular] the fact of not being part of or involved in a group or organization; **4.** (**the outside**) [singular] the part of a curving river, road or track furthest from the inner or shorter side of the curve, OPPOSITE: **the inside**; **on the outside** [idiom] used to describe how somebody appears or seems; [a] [only before noun] **1.** of, on or facing the outer side, SYNONYM: **external**, OPPOSITE: **inside**; **2.** not included in or connected with a particular group, organization, country, etc., OPPOSITE: **inside**; [prep] (also **outside of especially in North American English**) **1.** away from or not in a particular place, OPPOSITE: **inside**; **2.** on or to a place beyond the edge of something, OPPOSITE: **inside**; **3.** not part of something, OPPOSITE: **within**; **4.** (**outside of especially North American English**) apart from; [adv] **1.** near but not in a room, building or container, OPPOSITE: **inside**; **2.** not inside a building; outdoors.

<sup>565</sup>**expect** [v] **1.** to think or believe that something will happen or that somebody will do something; **2.** to demand that somebody will do something because it is their duty; **be (only) to be expected** [idiom] to be likely to happen; to be quite normal.

## 1.6 From Here to Tenure: Choosing a Career Path

“An unsentimental comparison of the merits of jobs in academia, industry, & in government laboratories.”

## 1.7 Job Interviews

“What will happen on your interview trip; the questions you had better be prepared to answer.”

## 1.8 Getting Funded

“What goes into an effective grant proposal; how & when to start writing one.”

## 1.9 Establishing a Research Program

“Tuning your research efforts to your own capabilities & your situation in life; e.g., why not to start a 5-year project when you have a 2-year postdoctoral appointment.”grasp

## 1.10 A Survival Checklist

“Do not attempt a takeoff before being sure the flaps are down.”

## 1.11 Afterthoughts

“A behaviorist approach to professional success.”



## Chapter 2

# Quanta Magazine

### 2.1 Wikipedia/Quanta Magazine

“*Quanta Magazine* is an editorially independent online publication of the Simons Foundation covering developments in physics, mathematics, biology, & computer science.

*Undark Magazine* described *Quanta Magazine* as “highly regarded for its masterful coverage of complex topics in science & math.” The science news aggregator *RealClearScience* ranked *Quanta Magazine* No. 1 on its list of “The Top 10 Websites for Science in 2018.” In 2020, the magazine received a National Magazine Award for General Excellence from the American Society of Magazine Editors for its “willingness to tackle some of the toughest & most difficult topics in science & math in a language that is accessible to the lay reader without condescension or oversimplification.”

The articles in the magazine are freely available to read online. *Scientific American*, *Wired*, *The Atlantic*, & *The Washington Post*, as well as international science publications like *Spektrum der Wissenschaft*, have reprinted articles from the magazine.” – Wikipedia/Quanta Magazine

#### 2.1.1 History

*Quanta Magazine* was initially launched as *Simons Science News* in Oct 2012, but it was renamed to its current title in Jul 2013. It was founded by the former *New York Times* journalist Thomas Lin, who is the magazine’s editor-in-chief. The 2 deputy editors are John Rennie & Michael Moyer, formerly of *Scientific American*, & the art director is Samuel Velasco.

In Nov 2018, MIT Press published 2 collections of articles from *Quanta Magazine*, *Alice & Bob Meet the Wall of Fire* & *The Prime Number Conspiracy*. In May 2022 the magazine’s staff, notably Natalie Wolchover, were awarded the Pulitzer Prize for Explanatory Reporting.” – Wikipedia/Quanta Magazine/history

### 2.2 Quanta Magazine/Elegant 6-Page Proof Reveals the Emergence of Random Structure

“2 young mathematicians have astonished their colleagues with a full proof of the Kahn–Kalai conjecture – a sweeping statement about how structure emerges in random sets & graphs.”

Fig. Will a random graph result in a triangle (right), a Hamiltonian cycle (center), or some other property of interest? – Olena Shmahalo for Quanta Magazine

“When the mathematicians Jeff Kahn & Gil Kalai 1st posed their “expectation threshold” conjecture in 2006, they didn’t believe it themselves. Their claim – a broad assertion about mathematical objects called *random graphs* – seemed too strong, too all-encompassing<sup>1</sup>, too bold to possibly be true. It felt more like wishful thinking than a reflection of mathematical truth. Even so, no one could prove it false, & it quickly became 1 of the most important open problems in the field.

Now, more than 15 years later, a pair of young mathematicians at Stanford University have done what Kahn & Kalai thought borderline impossible: In surprisingly short preprint posted online just a few weeks ago, Jinyoung Park & Huy Tuan Pham have provided a complete proof of the conjecture.

“It’s strikingly simple & ingenious<sup>2</sup>,” said Kalai. “It’s stunning<sup>3</sup>. It’s wonderful.”

The result automatically proves hundreds of more specific statements that would each be very difficult to prove on their own – & it has even deeper consequences for our understanding of random graphs & mathematical sets more broadly.

<sup>1</sup>all-encompassing [a] (formal) including everything.

<sup>2</sup>ingenious [a] 1. (of an object, a plan, an idea, etc.) very suitable for a particular purpose & resulting from clever new ideas; 2. (of a person) having a lot of clever new ideas & good at inventing things.

<sup>3</sup>stunning [a] (rather informal) 1. extremely attractive or impressive, SYNONYM: beautiful; 2. that surprises or shocks you very much.



“I would call their proof magical,” said **Jacob Fox**, a mathematician at Stanford & Pham’s doctoral adviser. “This is going to be a major part of the field going forward.”

### 2.2.1 Freezing a Graph

The Kahn–Kalai conjecture is very broad – it’s written in the abstract language of sets & their elements – but it can be understood by considering a simple case. 1st, imagine a graph: a set of points, or vertices, connected by lines, or edges. To make a random graph, take a biased coin – one that lands on heads with a probability of 1%, or 30%, or any other percentage between 0 & 100 – & flip it once for a given pair of vertices. If the coin lands on heads, connect those vertices with an edge; if the coin lands on tails, don’t. Repeat this process for every possible pair of vertices.

Fig. Jinyoung Park, a mathematician at Stanford University, “could feel the beauty & the strength of this conjecture,” she said. “But I never imagined that I would prove it.” – Rod Searcey

Mathematicians want to know when such a graph is likely to have some sort of interesting structure. Perhaps it will contain a triangle. Or maybe it will have a Hamiltonian cycle, a chain of edges that passes through every vertex exactly once. It’s possible to think about any property, so long as it is “increasing” – i.e., if adding more edges to a graph that already contains the property will not destroy the property.

If the probability of the coin turning up heads is low, edges will be rare, & properties like Hamiltonian cycles are not likely to arise. But if you dial up the probability, something strange happens. Each property has what’s called a *threshold*: a probability at which the structure emerges, often very abruptly<sup>4</sup>.

Just as ice crystals form when the temperature dips below zero degrees Celsius, the emergence of a particular property suddenly becomes extremely likely as more edges get added to the graph. When edges are added to a random graph of  $N$  vertices with a probability of less than  $\frac{\log N}{N}$ , e.g., the graph is unlikely to contain a Hamiltonian cycle. But when that probability is adjusted to be just a hair greater than  $\frac{\log N}{N}$ , a Hamiltonian cycle becomes extremely likely.

Mathematicians want to determine such thresholds for various properties of interest. “Thresholds are maybe the most basic thing you’d try to understand,” Fox said. “I look at a random object; does it have the property that I’m interested in?” Yet while the threshold has been calculated for Hamiltonian cycles & some other specific structures, in most cases it remains very difficult to determine a precise threshold, or even a good estimate of one.

So mathematicians often rely on an easier computation, one that provides a minimum possible value, or lower bound, for the threshold. This “expectation threshold” is calculated by essentially taking a weighted average. “The nice thing about this expectation threshold is it’s very easy to calculate,” said **David Conlon**, a mathematician at the California Institute of Technology. “Generally speaking, you can calculate this expectation threshold in like 2 lines for almost anything.”

But averages can be misleading. For Hamiltonian cycles, e.g., the expectation threshold is  $\frac{1}{N}$ , which is lower than the true value of  $\frac{\log N}{N}$  by a factor of  $\log(N)$ .

Fig. Gil Kalai at the Hebrew University of Jerusalem. – Daniel Vaaknin for Quanta Magazine

In 2006, Kahn & Kalai posited<sup>5</sup> that this was actually the worst-case scenario. Their eponymous<sup>6</sup> conjecture states that the gap between the expectation threshold & the true threshold will never be greater than a logarithmic factor. The conjecture, according to Conlon, “essentially takes what is the central question in random graphs & gives a general answer for it.”

But that’s just a simple case. The conjecture pertains to far more than random graphs. If true, it holds for random sequences of numbers, for generalizations of graphs called *hypergraphs*, & for even broader types of systems. That’s because Kahn & Kalai wrote their statement in terms of abstract sets. Random graphs constitute 1 specific case – a random graph can be thought of as a random subset of the set of all possible edges – but there are many other objects that fall within the conjecture’s purview. “Weirdly, when you’re dealing with graphs, proving it in that context would be very hard,” Conlon said. “But somehow, jumping to this abstract setting reveals the navel of the thing.”

It was this generality that made the statement seem so unbelievable. “It was a very brave conjecture,” said **Shachar Lovett**, a theoretical computer scientist at the University of California, San Diego. For 1 thing, it would instantaneously streamline a huge effort in combinatorics – trying to calculate thresholds for different properties. “Questions where seemingly the proofs needed to be very long & complicated suddenly just disappear,” said **Alan Frieze**, a mathematician at Carnegie Mellon University. “The proofs became just trivial application of this [conjecture].”

That so many seemingly unrelated problems could be settle by such a broad conjecture felt like a stretch to many mathematicians. “It seemed completely crazy, to be honest,” said Conlon. After devising their conjecture, Kahn & Kalai didn’t try to prove it. They worked to find a counterexample. There were so many settings they could explore, they figured they were bound to stumble across<sup>7</sup> one eventually.

<sup>4</sup>**abruptly** [adv] **1.** in a sudden, unexpected & often unpleasant way; **2.** in a way that seems rude & unfriendly, without taking time to say more than is necessary, SYNONYM: **brusquely, curtly.**

<sup>5</sup>**posit** [v] (*formal*) to suggest or accept that something is true so that it can be used as the basic for an argument or a discussion, SYNONYM: **postulate.**

<sup>6</sup>**eponymous** [a] [only before noun] the **eponymous** character of a book, play, film, etc. is the one mentioned in the title, SYNONYM: **titular.**

<sup>7</sup>**stumble across** [phrasal verb] **stumble across/on/upon something/somebody** to discover something/somebody unexpectedly.

But as it turned out, “the story evolved in a very different way” than they’d expected, Kalai said.

### 2.2.2 The sunflower Path

The methods that would eventually lead to the new proof of the Kahn–Kalai conjecture began with a breakthrough on a seemingly unrelated problem. In many ways, the story starts with the sunflower conjecture, a question posed by the mathematicians Paul Erdős & Richard Rado in 1960. The sunflower conjecture considers whether collections of sets can be constructed in ways that resemble the petals of a sunflower.

In 2019, Lovett was part of a team that came very close to a full solution of the sunflower problem, see [Quanta Magazine/Mathematicians Begin to Tame Wild ‘Sunflower’ Problem](#). At the time, the work seemed completely separate from the Kahn–Kalai conjecture, which involves considerations of probability. “I didn’t see any connection with our conjecture,” said Kalai. Neither did Lovett, who said that “we weren’t aware of these [other] questions. We cared about sunflowers.”

But Kah, Park (who was Kahn’s doctoral student at the time) & their colleagues ended up linking the 2 when they set out to prove a more relaxed version of the Kahn–Kalai conjecture a few months later. (Their proof was published in the *Annals of Mathematics* last year, see [Annals of Mathematics/Keith Frankston, Jeff Kahn, Bhargav Narayanan, Jinyoung Park. Thresholds vs. fractional expectation-thresholds](#)). This weaker version, formulated by the French mathematician Michel Talagrand, replaced the Kahn–Kalai expectation threshold with a “fractional” expectation threshold – essentially a different way of taking a weighted average. The revised definition “gives you more wiggle room to work with things,” Lovett said.

Kahn & Park’s team realized they could export techniques from the 2019 sunflower result, fine-tune them, & apply them to the Talagrand conjecture. “This is certainly what got us started,” said Kahn.

The mathematicians took an iterative approach to the problem. They set out to show that if they picked a random set – say, a random graph – it would contain a structure such as a Hamiltonian cycle. But instead of picking that random set all at once, they chose it in pieces, a process akin to the way Lovett & his colleagues approached the sunflower conjecture. “We perform some sort of random process iteratively,” Park said. “We choose some edges step by step” until they contain an entire Hamiltonian cycle.

To do this, the team turned to a notion of randomness called *spread*. If Hamiltonian cycles are “spread out” nicely, that means that not too many cycles contain the same edge or subset of edges. “Somehow, the collection of sets is spread out in space,” Pham said. “It’s not very clustered or concentrated on any part.” If the cycles are well distributed in this way, it guarantees that the process of random piece-by-piece containment – even if it fails for many Hamiltonian cycles – will succeed in capturing at least one.

The approach was possible only because of a critical equivalence: Spread could be quantified in a way that related directly to the fractional expectation threshold. Because of this, the mathematicians could rewrite the Talagrand conjecture in terms of spread.

Intriguingly, the proof of this weaker conjecture was enough to settle a torrent of threshold-related problems. “Every consequence that we know of for the full conjecture is also a consequence of the weak conjecture,” Kahn said. In fact, to him, Kalai & others, this suggested that the 2 conjectures might be more or less the same – that the values of the fractional & original expectation thresholds were basically equivalent. If someone could prove that equivalence, they’d prove the Kahn–Kalai conjecture. “I always thought the only way to prove our conjecture was to prove this,” Kahn said.

But that’s not what happened. While other mathematicians tried to follow this road map toward a full proof of the Kahn–Kalai conjecture, Park & Pham found a new approach altogether. “Jinyoung & Huy found this incredibly direct, incredibly short argument that just punches straight through all that,” Conlon said. “Which is extraordinary. I wasn’t expecting that at all.”

Kahn agreed. “This is 1 of the nice thing that happens in mathematics,” he said. “Things that people thought were hopeless turn out not only to be not hopeless, but not even hard.”

### 2.2.3 A Surprise Approach

At 1st, neither Park nor Pham had any intention of tackling the original conjecture. Since 1st learning about the problem as a graduate student, Park “could feel the beauty & the strength of this conjecture,” she said. “But I never imagined that I would prove it.”

“It was not in our mind at all,” Pham added.

Rather, they were working on another conjecture posed by Talagrand when they were “struck with a revelation,” Pham said. They realized that “the picture that we have here, the ideas that we have, it somehow seemed like it’s more powerful than it looked.” Those ideas, they thought, might just be powerful enough to take them all the way through a proof of the Kahn–Kalai problem.

Over the course of a single sleepless night in March, they figured out how to make the proof work.

Unlike the fractional expectation threshold, the normal expectation threshold has no relationship with spread. Spread “gives you a starting point. & if you go to the original, non-fractional conjecture, that starting point just disappears,” Kahn said. “So it looked very tough.”

“So what do you do?” Pham said. “In this case, we switch our perspective.”

“In particular, they thought about the problem in terms of a mathematical object called a *cover*. A *cover* is a collection of sets, where every object with a certain property contains 1 of those sets. E.g., 1 possible cover of all Hamiltonian cycles is the collection of all edges. Every Hamiltonian cycle will contain 1 of those edges.

Park & Pham rewrote the Kahn–Kalai conjecture in a way that let them make use of covers. The original conjecture puts constraints on what the probability of a weighted coin landing on heads should be in order to guarantee that a random graph or set contains some property. In particular, it says that the probability has to be at least the expectation threshold for the property multiplied by a logarithmic factor. Park & Pham turned this around: If such a property is not likely to emerge, then the probability assigned to the weighted coin is lower than the expectation threshold multiplied by a logarithmic factor.

That’s where covers come in: When a small cover can be constructed for a subset of structures (like a collection of Hamiltonian cycles), it means that the subset’s contribution to the expectation threshold is small. (Remember that the expectation threshold is calculated by taking a kind of weighted average over all possible structures of a given type.) So what Park & Pham now needed to show was that if a random set is unlikely to contain 1 target structure, there must exist a small cover for all such target structures. The bulk of their proof was dedicated to constructing that small cover.

They did this by using a similar piece-by-piece sampling process to the one used in the previous results, while also introducing what Fox called a “very clever counting argument.” 1 week after their sleepless night in March, they posted their elegant 6-page paper online.

“Their proof is super simple. They take the basic idea we developed & [the ideas from] these other papers & add a twist to it,” Lovett said. “& with this new twist, everything somehow becomes much, much easier.”

Frieze agreed. “I cannot explain it, but amazingly it’s true,” he said.

Just like the fractional result, the Kahn–Kalai conjecture, now proved true, automatically implies a cornucopia<sup>8</sup> of related conjectures. But more than that, “this is a powerful proof technique [that] will probably lead to new things,” said **Noga Alon**, a mathematician at Princeton University. “They had to do it in the right way.”

Park & Pham have now started to apply their method to other problems. They’re particularly interested in getting a more precise understanding of the gap between the expectation threshold & the real threshold. By proving the Kahn–Kalai conjecture, they’ve shown that this gap is at most a logarithmic factor – but sometimes the gap is smaller, or even nonexistent. At the moment, there’s no broader mechanism for classifying when each of these scenarios might be true; mathematicians have to work it out case by case. Now, “we think that with this efficient technique we have, we can hopefully be much more precise in pinning down these thresholds,” Pham said.

& their proof could have other consequences as well. “The Kahn–Kalai conjecture is not at all the end of the story,” Park said.” – Jordana Cepelewicz, Senior Writer

## 2.3 Quanta Magazine/Dennis Sullivan, Uniter of Topology & Chaos, Wins the Abel Prize

“The American mathematician invented entire new ways to understand shapes & spaces.”

Fig. DENNIS SULLIVAN at Stony Brook University. – John Griffin/Stony Brook University

“**Dennis Sullivan** has always been driven by mathematical insights that are general & beautiful & have the power to amaze – “something that grabs you, like a piece of music,” he said. An encounter with 1 such theorem during his 2nd year of college spurred him to switch his major from chemical engineering to mathematics; other encounters like it would later inspire him to spend years or even decades on a particular problem.

Now Sullivan, a mathematician at Stony Brook University & the City University of New York whose work in topology & dynamical systems has led to powerful new insights of his own, has been awarded the **Abel Prize**, 1 of the highest honors in mathematics. The prize committee recognized Sullivan “for his groundbreaking contribution to topology” – the study & classification of shapes – as well as his ability to decipher a wide range of mathematical problems by viewing them through a geometric lens.

“He has really been 1 of the most influential characters in modern topology ... since the 1960s,” said **Hans Munthe-Kaas**, a mathematician at the University of Bergen & the chair of the Abel Prize committee.

Sullivan has dedicated much of his career to understanding topological spaces called *manifolds* – spaces that look flat (or like an ordinary coordinate space) when viewed from any point on their surface, but that have a more complicated global structure. The structure of a sphere & the surface of a torus, e.g., are both 2D manifolds.

Sullivan set his sights on such shapes in higher dimensions. He provided a complete classification of manifolds of a particular type in 5 or more dimensions, & made significant progress on a problem related to different ways of **dividing manifolds into smaller triangular pieces**. In pursuit of both those goals, he helped to further develop an area called *surgery theory*, which involves changing 1 manifold into another by cutting & regluing pieces of it.

<sup>8</sup>**cornucopia** [n] **1.** (also **horn of plenty**) an object like an animal’s horn in shape, shown in art as full of fruit & flowers; **2.** (formal) something that is or contains a large supply of good things.

Some of his most groundbreaking work, delineated in [a set of notes circulated informally](#) in 1970, involved cutting to the core of “what it really means to have a space which has the topology of a manifold” by looking at it from other perspectives, Sullivan said.

Often, mathematicians study a topological shape by associating it with algebraic objects called *homotopy groups* that capture important properties of the shape. These groups might describe, e.g., how loops can intersect & be arranged in the space. But because the groups can be very difficult to compute, Sullivan helped develop a technique whereby the information “could be broken into boxes,” he said, & “each one could be treated separately.” Having made those simpler calculations, “you could get back the full story” & better understand the manifold of interest.

To do this, Sullivan essentially invented a notion of division, where loops on the original manifold were divided into 2 or 3 or more. Even though doing this meant replacing the manifold with a much more complicated-looking object, it allowed him to deal with homotopy groups that involved fractions rather than integers. & the introduction of fractions into the algebra “makes life much simpler when you’re counting things,” he said, & could be used to prove certain properties.

“It just enables a different kind of discourse,” said [Shmuel Weinberger](#), a mathematician at the University of Chicago. He compared Sullivan’s innovations to chemical or genetic analysis in that they “let you break things up into fundamental pieces that look extremely different from the original object.”

The technique itself wasn’t the part that stood out for Sullivan. “It was like an exercise to me,” he said. To him, what mattered more was that it allowed him to show that symmetry & other properties existed in this divided or “local” sense, which turned out to be crucial for proving certain statements that would have otherwise eluded him (including a notable result [Dennis Sullivan. Genetics of Homotopy Theory & the Adams Conjecture](#) related to the homotopy groups of spheres). He ultimately used this way of studying manifolds to prove several important results in topology.

“He was like a fresh wind from the outside” in terms of both his ideas & his personality, said [Nils Baas](#), a mathematician at the Norwegian University of Science & Technology, reflecting on when he 1st met Sullivan more than 50 years ago. “His contributions are so many & profound, this prize is well deserved.”

*“It’s just a great moment in the history of mathematics.”* – Étienne Ghys

Sullivan’s efforts to capture the very essence of a space didn’t stop there. In the late 1970s, in parallel with the mathematician Daniel Quillen, he founded what’s called [rational homotopy theory](#): a way to ignore certain information about the topology of a manifold so that the remaining information can be packaged in an easier, more tractable way.

The work was once again motivated by the fact that homotopy groups can often be nearly impossible to compute. “Spaces are really hard to understand. In some sense, we don’t even understand what spheres are from this purely [algebraic] point of view,” said [Ulrike Tillmann](#), a mathematician at the University of Oxford & a member of this year’s Abel Prize committee. Rational homotopy theory is geared toward simplifying that algebraic translation to something “much more tangible,” she said, so that mathematicians can still say something about the spaces they’re interested in & what those spaces are equivalent to.

In this streamlined context, Quillen & Sullivan used different algebraic models to understand their manifolds. Sullivan’s approach was notable because it relied on tools from calculus to capture information about different spaces. “He was much more concrete in his attack,” said Munthe-Kaas. “It allowed people to really compute with these structures.”

His invention of rational homotopy theory is “a wonderful piece of art,” said [Étienne Ghys](#) of the École Normale Supérieure in Lyon, France. “It’s just a great moment in the history of mathematics.” It provided the opportunity to study spaces in ways that had seemed completely inaccessible before.

Yet Sullivan described it once again as “an exercise.” What excited him, he said, was that it became the key to answering other questions he’d been wondering about, including one that resulted in what he called “the theorem of my life” – even though people hardly paid attention to it, focusing more on the development of rational homotopy theory & the doors it would open. “There’s no justice, in some sense,” he quipped.

Heading into the 1980s, Sullivan’s work was almost entirely focused on manifolds from what he called an “outside,” more global perspective – on in which, by definition, “the manifold doesn’t really have any local personality,” he said. “It doesn’t have a texture to its skin. It has no beauty marks. Every place looks like every other place . . . like a puddle of milk.”

He wanted to find that local personality. & so he switched gears & turned his attention to dynamical systems, the study of motion within or through a space. “A dynamical system has different textures in different parts of the manifolds,” he said. “Dynamics was really a new world.”

At that time, there was renewed interest in studying the complicated dynamics that could arise from the iteration of even simple functions. Consider a function like  $f(z) = z^2 + 1$ , & plug in a complex number (a number that has a real & an imaginary part). Then take the answer, plug it back into the function, & repeat. The result is a sequence of points that form elaborate fractal paths through the complex plane. Sullivan proved a 60-year-old conjecture [[Dennis Sullivan. Quasiconformal Homeomorphisms & Dynamics I. Solution of the Fatou-Julia Problem on Wandering Domains](#)] about how points (& their surrounding domains) in these kinds of systems eventually return to their starting place, rather than wandering around forever.

To demonstrate this & other results (including one related to the mathematics underlying a universal property of certain chaotic systems), he forged connections between 2 seemingly unrelated fields: the study of dynamical systems generated



from iterating functions, & the study of certain group of symmetries that act on a particular kind of geometric space. The so-called Sullivan’s dictionary “built bridges ... & changed both subjects,” said Weinberger

In the early 2000s, Sullivan returned to the outside view of topology that characterized the early years of his career. Alongside **Moira Chas**, a mathematician at Stony Brook (& his wife), he developed a new way to classify manifolds by studying loops & paths on their surfaces.

Now he’s begun to combine his interests in topology & dynamical systems even more seamlessly<sup>9</sup>. He is investigating fluid flows & the equations that describe them from a topological perspective.

“I’m not sure he sees the boundaries between different areas of mathematics the same as other people see it,” said Munthe-Kaas.” – Jordana Cepelewicz, Senior Writer

## 2.4 Quanta Magazine/How to Write Software with Mathematical Perfection

“LESLIE LAMPART revolutionized how computers talk to each other. Now he’s working on how engineers talk to their machines.”

Fig. Modern computers can effectively coordinate with each other because of the work of the computer scientist LESLIE LAMPART. He’s since turned his attention to making programming itself more efficient. – Talia Herman for Quanta Magazine

“**Leslie Lampart** may not be a household name, but he’s behind a few of them for computer scientists: the typesetting program  $\text{\LaTeX}$  & the work that made cloud infrastructure at Google & Amazon possible. He’s also brought more attention to a handful of problems, giving them distinctive names like the *bakery algorithm* & the *Byzantine Generals Problem*. This is no accident. The 81-year-old computer scientist is unusually<sup>10</sup> thoughtful about how people use & think about software.

In 2013, he won the A.M. Turing Award, considered the Nobel Prize of computing, for his work on distributed systems, where multiple components on different networks coordinate to achieve a common objective. Internet searches, cloud computing & artificial intelligence all involve orchestrating legions of powerful computing machines to work together. Of course, this kind of coordination opens you up to more problems.

“A distributed system is one in which the failure of a computer you didn’t even know existed can render your own computer unusable,” Lampart once said.

Among the biggest sources of problems are “concurrent systems,” where multiple computing operations happen during overlapping slices of time, leading to ambiguity: Which computer’s clock is the right one? In a seminal 1978 paper [**Time, clocks, & the ordering of events in a distributed system**], Lampart introduced the notion of “causality” to solve this issue, using an insight from special relativity. 2 observers may disagree on the order of events, but if 1 event causes another, that eliminates the ambiguity. & sending or receiving a message can establish causality among multiple processes. Logical clocks – now also called *Lampart clocks* – provided a standard way to reason about concurrent systems.

With this tool in hand, computer scientists next wondered how they could systematically make these connected computers even bigger, without adding bugs. Lampart came up with an elegant solution: Paxos, a “consensus algorithm” that allows multiple computers to execute complex tasks. Without Paxos & its family of algorithms, modern computing could not exist.

**Video.** **LESLIE LAMPART talks about the importance of programming instead of coding, how he developed distributed systems & his favorite algorithm.** – Photo by Talia Herman for Quanta Magazine; video by Emily Buder & Marcos Rocha for Quanta Magazine

In the early 1980s, as he developed the field, Lampart also created  $\text{\LaTeX}$ , a document preparation system that provides sophisticated ways to typeset complex formulas & format scientific documents.  $\text{\LaTeX}$  has become the standard for formatting papers not only in math & computer science but also in most scientific domains.

Lampart’s work since the 1990s has focused on “formal verification,” the use of mathematical proofs to verify the correctness of software & hardware systems. Notably, he created a “specification language” called **TLA+** (for Temporal Logical of Actions). A software specification is like a blueprint or a recipe for a program; it describes how software should behave on a high level. It’s not always necessary, since coding a simple program is akin to just boiling an egg. But a more complicated task with higher stakes – the coding equivalent of a 9-course banquet – requires more precision. You need to prepare each component of each dish, combine them in a precise ways, then serve them to every guest in the correct order. This requires exact recipes & instructions, written in unambiguous & succinct language, but descriptions written in English prose could leave room for misinterpretation. TLA+ employs the precise language of mathematics to prevent bugs & avoid design flaws.

Using your recipe, or specification, as an input, a program called a *model checker* will check whether the recipe makes sense & works as intended, producing a dish the way the chef wants it. Lampart laments how programmers often cobble together a system before writing a proper specification, whereas chefs would never cater a banquet without 1st knowing that their recipes will work.

<sup>9</sup>**seamlessly** [adv] smoothly, so that you do not notice any change between 1 part & the next.

<sup>10</sup>**unusually** [adv] **1.** used before adjectives to emphasize that a particular quality is greater than normal; **2.** used to say that a particular situation is not normal or expected.

Quanta spoke with Lamport about his work on distributed systems, what's wrong with computer science education, & how using TLA+ can help programmers build better systems. The interview has been condensed & edited for clarity.

**Question 2.1.** *Let's start with Paxos, since it's such an influential algorithm. What made you start working on it in the 1st place?*

People were building a system with some code, & I had the hunch<sup>11</sup> that what their code was trying to accomplish was impossible. So I decided to try to prove it, & instead came up with an algorithm that the people should have been using for their system.

**Question 2.2.** *What was wrong with their original algorithm?*

Well, they didn't have an algorithm, just a bunch of code. Very few programmers think in terms of algorithms. When trying to write a concurrent system, if you just code it without having algorithms, there's no way that your program is not going to be full of bugs.

Fig. Lamport visits the Computer History Museum in Mountain view, Calif. – Talia Herman for Quanta Magazine

**Question 2.3.** *The paper [Leslie Lamport. The part-time parliament] that introduced Paxos wasn't very widely read at 1st. Why was that?*

What made it impossible for people to read the paper was that I like explaining things with stories, & I made up names for characters in sort of pseudo-Greek letters. E.g., in the paper there was a cheese inspector named Γωνδα. Having grown up as a mathematician, where Greek letters were used all over the place, I was just unaware that nonmathematicians get completely freaked out by those letters. Apparently, the readers couldn't deal with it, & it caused that paper not to be read as it should have been.

So that didn't work as well at 1st. Although in the long run it did, because people call this family of consensus algorithms Paxos instead of “viewstamped replication”<sup>12</sup>, which was another name for the same algorithm from [the computer scientist] Barbara Liskov.

**Question 2.4.** *After working on distributed systems for so many years, what got you into TLA+?*

In the 1970s, when people were reasoning about programs, they were proving properties of the program itself stated in terms of programming languages. Then people realized that they should really be stating what the program is supposed to accomplish 1st – the program's behaviors.

In the early 1980s, I realized that 1 practical method of writing these higher-level specifications for concurrent systems was writing them as abstract algorithms. With TLA+, I was able to express them mathematically in a completely rigorous fashion. & everything clicked. What that involves is basically not trying to write algorithms in a programming language: If you really want to do things right, you need to write your algorithm in the terms of mathematics.

Fig. “The importance of thinking & writing before you code needs to be taught in undergraduate computer science courses & it's not,” Lamport said. – Talia Herman for Quanta Magazine

**Question 2.5.** *You've said, “If you're thinking without writing, you only think you're thinking.” Is that where model checking comes in?*

Model checking is a method for exhaustively testing all executions of a small model of the system. It just shows the correctness of the model, not of the algorithm. While model checking tests for correctness, coding just produces code. It doesn't test anything. Before there was model checking, the only way to be sure that your algorithm worked was to write a proof.

In practice, model checking checks all executions of a small instance of the algorithm. & if you're lucky, you can check large enough instances that it gives you enough confidence in the algorithm. But the proof can prove its correctness for a system of any size & for any use of the algorithm.

**Question 2.6.** *It sounds like model checking is related to another method of program verification: interactive theorem proving using tools such as Coq. How are they different?*

Coq was designed to do real mathematics to be able to capture the reasoning that mathematicians do. It's what Georges Gonthier used to prove the 4-color theorem, e.g. A machine-checked proof of a mathematical statement shows that the statement is almost certainly true.

TLA+ is designed not for mathematicians but for engineers who want to prove the properties of their systems. In the 1990s, after having spent about 15 years writing proofs of concurrent algorithms, I learned what you needed to do in order

<sup>11</sup>**hunch** [v] [intransitive, transitive] to bend the top part of your body forward & raise your shoulders & back; [n] a feeling that something is true even though you do not have any evidence to prove it.

<sup>12</sup>**replication** [n] [uncountable, countable] **1.** the act or process of producing the same thing again; **2.** the process by which genetic material, a cell or a virus makes a copy of itself.

to prove the correctness of a concurrent algorithm. TLA was the logic that allowed it to be all completely normal. & TLA+ is the complete language based on that.

Fig. Lamport won the A.M. Turing Award in 2013 for his work on computer coordination, a field known as *distributed systems*. His Paxos algorithm is now an industry standard. – Talia Herman for Quanta Magazine

**Question 2.7.** *Specification languages like TLA+ aren't used very widely in industry, right? Why do you think that is?*

Well, **I'm doing what I can**. But basically, programmers & many (if not most) computer scientists are terrified by math. So that's a tough sell.

2ndly, every project has to be done in a rush. There's an old saying, "There's never time to do it right. There's always time to do it over." Because TLA+ involves upfront effort, you're adding a new step in the development process, & that's also a hard sell.

**Question 2.8.** *Is it always worth that upfront effort?*

True, most of the code written by programmers across the world doesn't require very precise statements about what it's supposed to do. But there are things that are important & need to be correct.

When people build a chip, they want that chip to work right. When people build a cloud infrastructure, they don't want bugs that will lose people's data. For the kind of application where precision is important, you need to be very rigorous. & you need something like TLA+, especially if there's concurrency involved, which there usually is in these systems.

Fig. The specification language TLA+, developed by Lamport over the past few decades, allows engineers to describe a program's goals in a precise, mathematical way. – Talia Herman for Quanta Magazine

**Question 2.9.** *Are programmers biased in terms of spending more time writing code than they do thinking about it?*

Yes, the important of thinking & writing before you code needs to be taught in undergraduate computer science courses & it's not. & the reason is that there's no communication between the people who teach programming & the people who teach program verification.

From what I've seen, the fault lies on both sides of that divide. The people who teach programming don't know the verification that they need to know. The people who are teaching verification don't understand how it should be applied & used in practice.

Until that divide is bridged, TLA+ is not going to find a large number of users. I hope I could at least get the people who teach concurrent programming to understand that they need it. Then maybe there's some hope.

**Question 2.10.** *I get the sense that you aren't too happy with computer science education these days. Is it because it doesn't put enough emphasis on mathematics?*

On mathematical thinking, yeah.

**Question 2.11.** *How would you structure an undergraduate curriculum, then?*

I'm not an educator, so I don't know how to teach it to them. But I know what people should have learned. They shouldn't be afraid of math. It's just simple math that they've probably taken a course in, but they don't know how to use it. They don't know what good it is. They learn enough to pass the exam & then they forget about it.

**Question 2.12.** *Mathematicians often say they see beauty in math. You started out in that field, so do you see beauty in algorithms?*

I don't think in terms of aesthetics<sup>13</sup>. I probably have the kinds of feelings that other people do, but I just use different words to express them. Being beautiful is not something I would say about an algorithm. But simplicity is something that I value highly.

**Question 2.13.** *1 last thing, about another side project of yours with a sizable impact: L<sup>A</sup>T<sub>E</sub>X. I'd like to finally clear something up with the creator. Is it pronounced LAH-tekh or LAY-tekh?*

Any way you want. I don't advise spending very much time thinking about it." – Sheon Han, Contributing Writer

<sup>13</sup>**aesthetic** [a] (*North American English also esthetic*) **1.** concerned with beauty & art & the understanding of beautiful things; **2.** beautiful to look at; [n] **1.** [countable] **aesthetic (of something)** a set of principles that express the aesthetic qualities & ideas of a particular artist or a particular group of artists, writers, etc.; **2.** (**aesthetics**) [uncountable] the branch of philosophy that studies the principles of beauty, especially in art.

## 2.5 Quanta Magazine/The Computer Scientist Who Can't Stop Telling Stories

“For pioneering computer scientist Donald Knuth, good coding is synonymous with beautiful expression.” Donald Knuth has worked his whole life to tell stories with & about computer programs. “Donald Knuth is a computer scientist who came of age with his field. During the nascent<sup>14</sup> years of computer programming in the middle of the last century, a candy company ran a contest that summoned his talents as a 13-year-old. The contest asked kids to determine how many words could be made from the letters of the candy’s name: Ziegler’s Giant Bar. It was a well-defined problem with distinct pieces, just the kind he loved.

“I had an obsessive-compulsive streak that drew me to digital, discrete problems. & I loved poring over large collections of information,” Knuth said.

Knuth methodically<sup>15</sup> leafed through<sup>16</sup> his family’s 2,000-page funk & Wagnalls unabridged<sup>17</sup> dictionary in the basement. He even convinced his parents he was sick, winning himself 2 weeks away from school to work on the problem. After labeling index cards with headings such as “Aa,” “Ab” & “Ba” based on the beginnings of possible words using letters from the candy’s name, he went down the dictionary’s columns noting words that qualified. He found that he could skip entire sections of the dictionary, such as pages for words starting with the letter “C,” or sections of the “B” words whose 2nd letter was “U.”

The contest officials had identified approximately 2,000 words they could expect, but Knuth found > 4,700. He was rewarded with a spot on television & chocolate for his entire class. He would go on to win many more accolades<sup>18</sup>, including the 1st **ACM Grace Murry Hopper Award**, the **National Medal of Science** & the **A. M. Turing Award**.

Knuth eventually merged his dual loves of discrete digital problems & large collections of information in his magnum opus<sup>19</sup>, *The Art of Computer Programming* – a book series he began writing as a graduate student in 1962 & has yet to complete. He published volume 1 in 1968, & the current version is in its 42nd printing. Volume 2 followed in 1969 & volume 3 in 1973. By then he was a computer science professor at Stanford University, but he worried that his work would prevent him from completing his books. So he took a leave of absence in 1990 & then retired in 1993 to spend the rest of his life completing the 7-volume set. Now 82, he’s hard at work on part B of volume 4, & he anticipates that the book will have at least parts A through F. Knuth is currently working on volume 4, part B, of *The Art of Computer Programming*. He expects it to have at least 4 more parts, & the whole set to have 3 more volumes. *The Art of Computer Programming* is more than a how-to manual. Just as Isaac Asimov & Eric Temple Bell wove narratives & characters into their science & math stories, Knuth delights in telling stories of computer science. “The best way to communicate from 1 human being to another is through story,” he said. This passion for communication helped him play another starring role in the story of computer science beyond his magnum opus. When his publisher sent him galley proofs for the 2nd edition of Vol. 2 in the 1970s, Knuth was disturbed by the arrangement & appearance of the numbers, symbols & words on the pages. He flew to Los Angeles to see a machine that printed glossy magazines digitally, hoping it could provide aesthetic relief, but it was too expensive. Nonetheless, on that trip he began developing a computer language that would allow him to typeset mathematics digitally.

“I’m unable to resist a good story. I viewed myself not as a pioneer, but as a journalist.” – Donald Knuth

Back at Stanford, Knuth put aside *The Art of Computer Programming* for nearly a decade to develop **T<sub>E</sub>X** (pronounced “tech”), a sophisticated, game-changing program that put digital typography on a desktop computer. He made it open source, much to the benefit of professional mathematicians, computer scientists, economists, engineers, linguists, statisticians, & anyone else who lacked technical symbols on their keyboards but understood the placement of complicated formulas better than their publishers. In a world of often ephemeral<sup>20</sup> computer programs, T<sub>E</sub>X has endured as the gold standard for making scientific papers more beautiful & easier for experts to read & understand.

Knuth’s interest in storytelling also led him to develop a philosophy of **literate programming** – a method for writing computer programs as literary essays. A literate program intersperses source code with elegant prose written in a familiar language, such as English. The source code delivers functionality & efficiency, while the exposition addresses a human reader, rather than the computer’s compiler. Anyone who later updates or debugs a literate program will avoid the often time-consuming & costly problem of trying to understand the original programmer’s algorithms, design decisions & implementation strategies. Knuth is a computer scientist who understands that words matter.

*Quanta Magazine* spoke with Knuth in Feb at his home on the Stanford campus. The interview has been condensed & edited for clarity.

<sup>14</sup>**nascent** [a] (*formal*) beginning to exist; not yet fully developed.

<sup>15</sup>**methodical** [a] **1.** done in a careful & logical way; **2.** (of a person) doing things in a careful & logical way.

<sup>16</sup>**leaf through** [phrasal verb] **leaf through something** to quickly turn over the pages of a book, etc. without reading them or looking at them carefully.

<sup>17</sup>**unabridged** [a] (of a novel, play, speech, etc.) complete, without being made shorter in any way, **OPPOSITE:** **abridged**.

<sup>18</sup>**accolade** [n] (*formal*) praise or an award for an achievement that people admire.

<sup>19</sup>**magnum opus** [n] [singular] (from Latin) a large & important work of art, literature or music, especially one that people think is the best work ever produced by that artist, writer, etc.

<sup>20</sup>**ephemeral** [a] (*formal*) lasting or used for only a short period of time, **SYNONYM:** **short-lived**.



**Question 2.14.** *Have you always been interested in writing?*

Early on, I was advised that the read world would be too hard for me. I didn't expect to discover anything new, but I loved conveying my enjoyment of ideas in writing.

In 6th grade, a couple fiends & I started a 2-page paper on a ditto machine. We had jokes. In high school, every Monday night as the newspaper editor, I did an all-nighter to get the paper out. I saw my 1st line of type in college as the student paper copy editor. In my junior & senior years, we started the engineering & science review. E.g., I wrote, "Th<sub>5</sub>E<sub>4</sub>CH<sub>3</sub>EmIC<sub>2</sub>Al<sub>2</sub>Ca<sub>3</sub>P<sub>4</sub>Er." Every word was a chemical formula. Knuth has always told stories, with a science twist. In college, he penned a short story where each word was a chemical formula.

**Question 2.15.** *ℰ that led to your magnum opus? Do you think of it as another story?*

*The Art of Computer Programming* is a manifesto<sup>21</sup>. It describes the way I love to do math & the way I wish I had been taught. Beginning on p. 1, I tell the story of algorithms. Most textbooks at the time didn't explore the human side of discoveries. They just said, "This is how chemistry works," or "This is how physics works."

I also tell a technical story. I say, "Here's something that doesn't work, & here's a way to solve that problem." Instead of presenting only facts, I add drama. Science is much easier to learn if you know the sequence of discoveries. Also, I'm unable to resist a good story. I viewed myself not as a pioneer, but as a journalist.

**Question 2.16.** *Beyond the story, then, what's The Art of Computer Programming about?*

After 2 years of writing my book, I realized that its novelty<sup>22</sup> was quantitative<sup>23</sup> determining how good a program is. I didn't just want to say 1 program was better than another. I wanted to say one is 13.8% better than another, & explain how to compare them.

Author A would talk about Algorithm a, & author B would talk about his competing algorithm B. & author A never wrote about algorithm B, & author B never wrote about algorithm A. Also, authors A & B used different computers. As a neutral journalist, I explained both from 1 point of view. Asking, "How good is an algorithm really?" is a fun problem. That's the analysis of algorithms.

**Question 2.17.** *Is "the analysis of algorithms" just a different way of saying "the art of computer programming"?*

I was at a Society for Industrial & Applied Mathematics conference in 1967 when somebody asked what I did. In those days, computer science was partitioned into numerical analysis, artificial intelligence & programming languages. That was it. I realized I needed a name for what I do.

My book's novelty was its rigorous studies of how good the algorithms were. I decided that the next time I was asked this question, I would say, "Analysis of algorithms." My definition was: "If I'm interested in it, it's the analysis of algorithms. It wasn't a very good definition.

Later, I decided to justify it. I decided it was the quantitative study of how good an algorithm is, which I divided into 2 parts. 1 part considered all possible algorithms for a certain problem. The other part considered 1 particular algorithm for a certain problem.

"I knew computer programming could make books look good again."

Analysis of algorithms was going to be my life's work. I told my publisher to change the title of my book to *The Analysis of Algorithms*. My publisher said, "That will never sell." They made the right decision. Still, I was happy when, 40 years later, 5 or 6 books came out with the title *Analysis of Algorithms*.

**Question 2.18.** *But for you, programming is also about more than functionality. When you designed T<sub>E</sub>X e.g., you wanted to find "the most pleasing curve" that connects certain points. Were you trying to program beauty?*

My program had to connect points in some way that reverse-engineered what a good calligrapher would do. The letter "S" comes to a point where the curvature changes from positive to negative. Then maybe it stays steady for a while. The letter's designers followed some logic to make lines into letter shapes. I wanted to capture not only the design's outcome, but the intelligence behind it. That's like writing a computer program.

I talked to designers to understand what they were trying to achieve. The math was there to capture the design in a quantitative way. With mathematics, I put little dials on everything. I could say the letter "A" has got this point, that thickness, angles here, tapering there, a hump in the bottom & a certain serif length.

I never intended to replace designers. I only wanted to capture for future generations exactly what we were doing then. With T<sub>E</sub>X, a design is reproducible.

<sup>21</sup>**manifesto** [n] (plural **manifestos**) a written public statement of policy & aims, especially one made before an election by a political party or candidate.

<sup>22</sup>**novelty** [n] (plural **novelties**) **1.** [uncountable] **novelty (of something)** the quality of being new, different, & interesting; **2.** [countable] a thing, person or situation that is interesting because it is new, unusual or has not been known before.

<sup>23</sup>**quantitative** [a] [usually before noun] connected with or measuring the amount or number of something rather than its quality.

**Question 2.19.** *Did you anticipate T<sub>E</sub>X's global acceptance or its ability to endure?*

T<sub>E</sub>X was only supposed to be for my secretary & myself. Phyllis [Astrid Benson Winkler] was a wonderful secretary. She could read my handwriting & make it beautiful. Printing technology was going down the tubes because the tried-&-true methods were becoming too expensive. Nearly every piece of mathematics published in the 1970s looked atrocious<sup>24</sup>. In the *American Mathematical Monthly*, the subscripts were in a different font from main-line text. I knew computer programming could make books look good again.

I finished debugging a trial version of T<sub>E</sub>X in Apr 1978. In May, I had 10 users. In Jun, I had 100 users. In Jul, I had 1,000. Each new group would say, "You've gotta have this feature." 5 years later, I released what is essentially the T<sub>E</sub>X we have now. That was designed for Americans. Then the Europeans started to use it. So in the 1980s, I made it work for world languages.

**Question 2.20.** *It sounds like discovery has always been part of your process. Does that remain true today?*

I write an average of 5 new programs every week. Poets have to write poems. I have to write computer programs.

The ultimate test of whether I understand something is if I can explain it to a computer. I can say something to you & you'll nod your head, but I'm not sure that I explained it well. But the computer doesn't nod its head. It repeats back exactly what I tell it. In most of life, you can bluff<sup>25</sup>, but not with computers. "The best way to communicate from 1 human being to another is through story," Knuth said. This approach allowed him to analyze algorithms more rigorously & neutrally.

**Question 2.21.** *You spend your days writing, but you also have other interests. How do you approach each day?*

Jack London wrote 1,000 words every day before talking to anybody. He was totally, "Let me alone until I've got my thousand words!" Then he would drink or proofread the rest of the day. No, my scheduling principle is to do the thing I hate most on my to-do list. By week's end, I'm very happy.

**Question 2.22.** *Really? How does doing what you hate make you happy?*

It would be very easy for me to say, "Oh, let me be a genius & never clean the toilet." But even cleaning toilets is doable. [My wife] Jill & I got uniforms that have a slot where the 409 cleaner fits. You go over there & squirt & feel good cleaning the toilet!

A person's success in life is determined by having a high minimum, not a high maximum. If you can do something really well but there are other things at which you're failing, the latter will hold you back. But if almost everything you do is up there, then you've got a good life. & so I try to learn how to get through things that others find unpleasant. Knuth at his home in 2020. He retired in 1993 to complete his magnum opus, *The Art of Computer Programming*.

**Question 2.23.** *You also have many projects that have nothing to do with computer science, such as your musical composition, *Fantasia Apocalyptica*. You even built your house around a 2-story pipe organ. Is this variety also part what makes you happy?*

I wrote a couple of books, including *Things a Computer Scientist Rarely Talks About*, that are about theology<sup>26</sup> – things you can't prove – rather than mathematics or computer science. My life would not be complete if it was all about cut & dried things. The mystical things I don't understand give me humility<sup>27</sup>. There are things beyond my understanding.

In mathematics, I know when a theorem is correct. I like that. But I wouldn't have much of a life if everything were doable<sup>28</sup>. This knowledge doesn't tear me apart. Rather, it ensures I don't get stuck in a rut.

**Question 2.24.** *Does it matter if you finish The Art of Computer Programming?*

Oh, I realize that computer science will keep living & developing. 1 scenario is that everybody will stop working on the kinds of computers we have now. They'll all go to machine learning & use quantum computers. Then I could come to the end of the story of non-quantum computers. I'm happier when I can say, "This is the story's end." That's the easiest way to imagine that I'll finish. But I'm not answering your question.

Do you know the story of Tristram Shandy? Laurence Sterne, in the late 1700s, wrote an autobiographical book, *The Life & Opinions of Tristram Shandy, Gentleman*, which he published in fascicles, or installments. It has about 100 pages

<sup>24</sup>**atrocious** [a] **1.** very bad or unpleasant, SYNONYM: **terrible**; **2.** very cruel & making you feel shocked.

<sup>25</sup>**bluff** [v] [intransitive, transitive] **bluff (something)** to try to make somebody believe that you will do something that you do not really intend to do, or that you know something that you do not really know; [n] **1.** [uncountable, countable] an attempt to trick somebody by making them believe that you will do something when you really have no intention of doing it, or that you know something when you do not, in fact, know it; **2.** [countable] a steep cliff or slope, especially by the sea or a river; **call somebody's bluff** [idiom] to tell somebody to do what they are threatening to do, because you believe that they will not be cruel or brave enough to do it; [a] (of people or their manner) very direct & cheerful, with good intentions, although not always very polite.

<sup>26</sup>**theology** [n] (plural **theologies**) **1.** [uncountable] the study of religion & beliefs; **2.** [countable] a set of religious beliefs.

<sup>27</sup>**humility** [n] [uncountable] the quality of not thinking that you are better than other people; the quality of being humble.

<sup>28</sup>**doable** [a] (*informal*) **1.** [not usually before noun] able to be done; **2.** (BE) sexually attractive.

just on his 1st week of life. He wants the life story to be complete but, of course, he won't make it. Sterne wrote Tristram Shandy's story until he couldn't write anymore.

I want to continue writing good content in the best way I know, & cover things for which I have something original to say. I'll do as much of that as I can, instead of saying that I've got to finish by a certain deadline. I've been so fortunate riding waves & being born at a time that was just right for my particular peculiarity<sup>29</sup>. I've now achieved all of my life's goals except *The Art of Computer Programming*. I'm in a situation where I'll continue telling whatever stories I find & passing them on." – Susan D'Agostino, Contributing Writer

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<sup>29</sup>**peculiarity** [n] (plural **peculiarities**) **1.** [countable] **peculiarity (of somebody/something)** a feature that only belongs to 1 particular person, thing, place, etc.; **2.** [countable] **peculiarity (of somebody/something)** a strange or unusual feature or habit; **3.** [uncountable] **peculiarity (of somebody/something)** the quality of being strange or unusual.

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