Notes

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Panel 3: Galdikas saw her first wild orangutans on the second day out of Camp Leakey (named for her mentor Louis Leakey). This boded well, since other researchers who attempted to study them had far less success. One two-month study went without a single sighting. During another 52 day survey a Japanese primatologist saw only one, and other studies have settled for drawing conclusions from counting empty nests.

Page 95

Panel 2: Mr. Soegito served as Galdikas' government liaison and became, along with his boss Mr. Sinaga, a friend and ally.

Panel 3*:* Acidic sap from logs and insect bites combined with the ever-present damp result in constant rashes and skin problems.

Page 96

Panels 2-3: While she worked on her Ph.D. thesis, Galdikas and Rod Brindamour (her husband at the time) cut and marked over 125 kilometers of trails, staked and mapped every 25 meters, through the Tanjung Puting reserve. Literally thousands of species make their home there.

Panel 6: Aboriginal farmers clear *ramen* trees and harvest *jelung* sap. *Sirap* (roof slat makers) cut down ironwood trees, mostly working them where they fall. Illegal foresting results in dry rice fields called *ladang*.

Page 98

Biruté Galdikas has re-introduced a number of orangutans to the wild. Though owning orangutans is technically illegal, most government officials look the other way, and some keep captive orangutans themselves. Shortly after coming to Borneo Galdikas realized that her mission would have to consist of conservation in addition to study. She has since devoted much of her time and effort to gaining respect for herself and her mission, and much less on traditional academic awards. As an example, she wrote her first book on orangutan adaptation in Indonesian (as opposed to English), and works to amass the political power needed to save orangutans and their habitat.

Panel 3: The spiky fruit Sinaga peels is the durian, a delicacy for orangutans—and daring humans. It's famous for its delicious, creamy interior and its uniquely foul smell. Patricia Martin, in an article entitled "'Never', she said, 'Not even with a gas mask'" appearing in the Costa Rican *Tico Times* (4/24/98, page W-12) quoted some brave diners as saying it's like a sauerkraut sundae, or eating custard in a sewer.

Page 99

Panels 4-5: Fatigue and illness both contribute to the difficulty of doing field work, but boredom may be the biggest problem in Borneo: Jane Goodall commented that it took Galdikas two years to observe as much social activity as Goodall could see in two hours of watching Gombe's chimpanzees. Further, the environment itself is hostile, not only to researchers but to their equipment. Boot leather isn't the only thing that decays—the intense heat and humidity rots clothing and enables fungi to bloom in cameras.

Panels 7-9: Initially, researchers believed orangutans to be completely arboreal. While this is largely true of females, who

spend on average only 3 minutes of each day on the ground, males spend a little over an hour a day out of the trees.
Panel 8: By turning his back, Sinaga was showing her the height of orangutan respect. When describing a similar encounter with another rehabilitated orangutan named Ralph, Galdikas wrote: "What I [took] as indifference and rejection was the orangutan expression of acceptance. I had measured orangutans by human standards of sociability, and had misunderstood… Irrationally, I had joined the mothers who complain, 'They never call, they never write.'"

Creating conditions where observations can proceed without conflict or fear (on the part of either party) is one of the most challenging aspects of field research.

Page 100

Panel 2: At the time of her initial study, tool use was virtually unknown among orangutans. It took Galdikas five years to observe it in the wild. She had seen it in camp, but mostly in terms of her ex-captives dismantling things like her water pump.

Panel 8: Over the course of her thesis research, Galdikas' contact with target animals ranged from one minute to 65 consecutive days, resulting in almost 7,000 hours of direct observation. In contrast with her work, which has lasted more than 26 years at the time of this writing, the only Westerners to do long-term studies in Borneo were David Horr (who observed orangutans for a little over two years) and John MacKinnon (who did 1,200 hours of observation).

Page 101

Panel 1: Galdikas can indeed tell from the teeth marks if a male or female has eaten from a branch.

Panel 3: Though banitan pits have sweet tasting meats inside, they are difficult to get to. Orangutans don't get impatient with cracking them, though. In fact, Galdikas found her own impatience at odds not only with her subjects, but with the local people as well. As she describes it: "The Javanese believe that time is infinite. Time never runs out. Since there is always enough, time has little meaning."

Panel 6: 'Mast fruiting', when all of the trees bear fruit at the same time, offers high times to orangutans. But as Galdikas notes: "[A]lthough the forests look lush, there actually is very little to eat in any one place. This is why the tropics have been called a 'counterfeit paradise'." One instance of this is the so-called empty harvest: sometimes fruit will look perfect on the outside, but will be unripe, inedible, or perhaps even empty or rotten inside.

Page 102

Panels 1-3: Close association for traveling orangutans means they stay within 10-20 meters of each other. Bigger groups of any sort are rare—the largest Galdikas has observed is nine, and the most she has ever seen traveling together is five.

Panel 5: Both males and females have home ranges, though a male's is typically larger and more complex. These ranges relate to the scarcity of food in the jungle, since even though orangutans eat more than 300 types of plants and insects, the density of good food is low.

Panel 8: Baby orangutans cling to their mothers constantly for the first 18 months of their lives.

Page 103

Panels 1-2: Like chimpanzees, orangutans only form temporary associations. They differ from chimps mainly in the behavior of the adult males. The only close associations adult male orangutans form are with females, and even these are fairly rare. (It's a wonder they mate at all!) Chimpanzee males form more close bonds with other males than with females. Gorillas, like humans, organize into permanent groups.

Panel 4: Lip-smacking is an expression of anger. Though it is speech, scientists don't consider it language. Galdikas says orangutans "…don't need phonemes, words, and sentences. Quite simply, they have nothing to say to one another that can't easily be communicated through facial expressions, gestures, movements, and vocalizations."

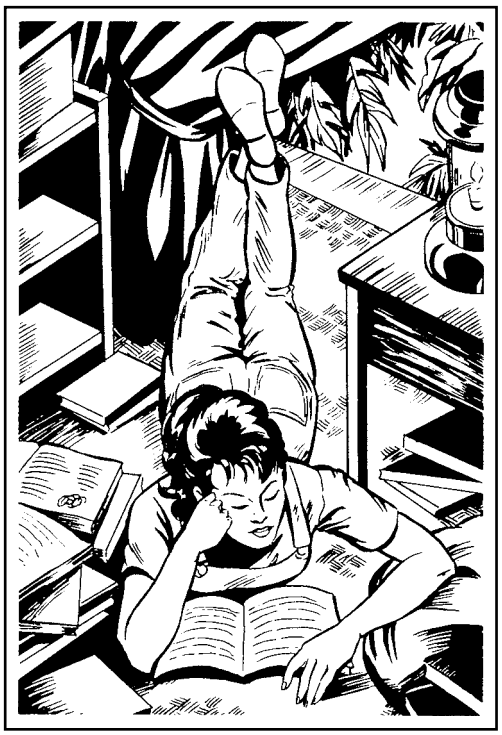
Panel 8: The fact that close association between orangutans is usually 10-20 meters relates not only to the scarcity of food, but also to how they travel: they bend the tops of trees and ride them like pole vaulters.

Page 104

Panel 5: Orangutans—females especially, since males will occasionally fight with each other, sometimes to the death—have no natural predators, so it's rare to see them frightened.

Page 108

Panels 1-3: Making direct eye contact is both aggressive and dangerous. The Melayu people have many stories about people fighting with orangutans. In these stories the orangutans always win.



Panel 4: Mature male orangutans look very different from females and sub-adult males. In fact, their appearance is so different that some aboriginal people consider the adult male orangutan an entirely separate species.

Panels 7-9: Unlike humans, orangutans do not appear to use trial and error. Instead, they seem to contemplate problems and suddenly (insightfully) arrive at a solution. Laboratory researchers call the *a-ha!* experience TP has here 'insight learning'.

Page 109

Panel 6: Wild orangutans don't taste, but do inspect, handle, and sniff new food. This is mainly because they almost never *try* new foods. Their behavior in captivity

is another matter, and in some respects all too human. According to Galdikas: "Given a choice between a juicy, sun-ripened, golden pineapple and a gooey, fat-laden milk chocolate bar or a Tootsie Pop, I have never known an ex-captive orangutan to choose the former."

Page 110

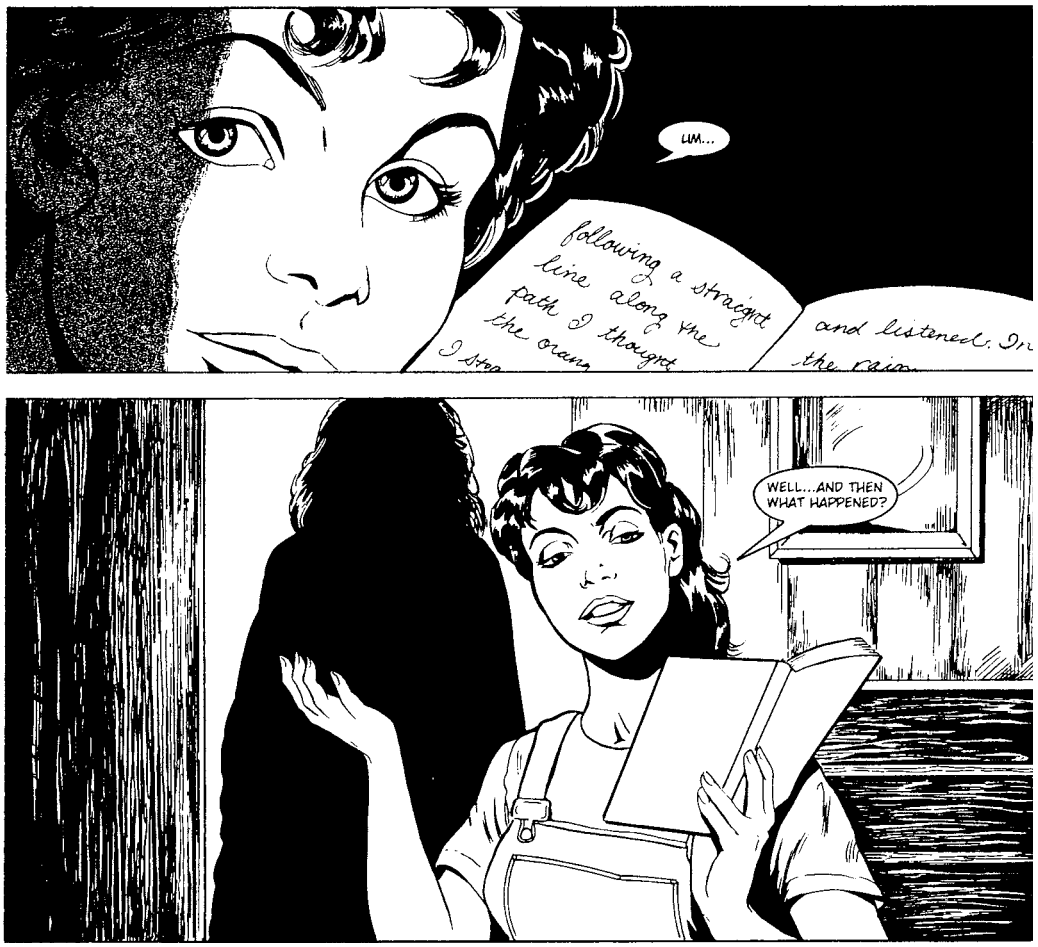
Mature males appear to be totally intolerant of each other. Aggressive encounters with other males can lead to fights to the death.

Page 111

This journal entry is quoted, almost verbatim, from Galdikas' book *Reflections of Eden*.

Page 113

Though Galdikas has studied orangutans longer than anyone else, to this day much of their behavior remains a mystery. The combination of human population pressure and recent drought (resulting in fires that have done even more damage to their habitat) makes continued research and discovery, not to mention conservation, all the more challenging.



Before offering suggestions for further reading in the guise of acknowledging the sources for these stories, two books in particular deserve notice above all others.

The first is *Nobel Prize Women in Science*, by Sharon Bertsch McGrayne (NY: Birch Lane Press, 1993). If you only read one other book as a result of *Dignifying Science*, please make it this one. It's enjoyable, succinct, and you'll recognize many of the people you just read about. Further, it will introduce you to many more important figures. A newer, expanded edition became available in 1998.

Women in science are not a historical curiosity, of course. For personal accounts by today's working scientists, read *Journeys of Women in Science and Engineering: No Universal Constant*, by Susan A. Ambrose, Kristin L. Dunkle, Barbara B. Lazarus, Indira Nair, and Deborah A. Harkus (Philadelphia: Temple University Press, 1997). History in the making told by the people making it.

Prologue: Marie Sklodovska

The motivation to *not* include Mme. Curie (née Sklodovska) in a book about women scientists is rather strong—if people know about anybody, she's the one. Better to focus on lesser known figures, perhaps. But reading her correspondence proved enough to force my reluctant hand, and the image of a scientist trying to trick herself into feeling warm by using the weight of furniture in place of blankets struck me as heartbreaking and funny in equal measure.

Reference

Madame Curie, by Eve Curie, translated by Vincent Sheean (NY: Garden City Publishing, 1940).

The letter to her brother used as (con)text for the prologue comes from this affectionate biography written by her youngest daughter. Eve Curie's description of her mother's early years of deprivation and optimism are particularly inspiring. The book is full of quotes that seemed like they ought to fit in a book of this sort but somehow didn't. They're too good to omit, though, so here they are:

> "Marie Curie is, of all celebrated beings, the only one whom fame has not corrupted."
> — Albert Einstein

> "In science we must be interested in things, not in persons."
> — Mme. Curie to a reporter who tracked her down during a vacation

Hedy Lamarr

Hedy Lamarr might seem an awkward or forced choice for inclusion in this book. Unlike the others featured here, she clearly did not devote her life to science. (In fact, her contribution was limited, and more along the lines of engineering than the pure science of all the others.) But besides her story being unusual, interesting, and so unlikely *vis-à-vis* her public persona as a film star, I think her appropriate to include for one important reason: She's sadly typical. At almost every turn others actively discouraged her from pursuing her talents in this 'male' direction. Though it only occupied a small part of her life, her aptitude for invention was important to her. Further, her co-inventor George Antheil asserts that she was rather indifferent to her acting career by the time of their work together. There's no telling what she might have accomplished had she devoted her efforts to the National Inventor's Council. She might not have created anything else as important as her first patent, but then again…

In more recent times she might have been encouraged (or at least permitted) to pursue her interest in invention. Today Hollywood would make a big deal of her affinity for science, especially since her patent is a fundamental part of that most important of all movie-making tools, the cellular phone. She got no support or acclaim from the studio system of the 1940s, though. But long after her films stop appearing on screens we'll dial up friends using the technology she invented to knock out Nazi U-boats.

Notes

Page 15

Panel 1: Fritz Mandl, Lamarr's handsome but cruel (sounds like something out of the Brothers Grimm, doesn't it?) first husband, spent two years and much of his fortune trying to wipe out the film. The negative was actually destroyed much later when the Russians invaded Budapest.

Page 17

Though *Ecstasy* is the first movie she became known for, Lamarr (Hedy Kiesler at the time) had her first bit part in the ironically titled *The Weaker Sex*. Most people recall *Ecstasy* as being scandalous because it showed Lamarr (from a great distance) running naked through the woods, but what really got everybody all riled at the time was the scene of her character in the throes of passion. The U.S. Commissioner of Customs report objected (in part) to "[t]hat portion of the film beginning with the engineer placing the girl on the couch and ending with the girl caressing his head as he sits on the floor…" Tame by today's standards—little would be cut even for television—it was banned in the U.S. until 1940, and until even later in Great Britain, as we'll see in the Rosalind Franklin story.

Page 18

Panels 5-6: Mussolini and Mandl refer to both Mandl's former wife Hella Strauss (a Viennese beauty) and to the affair he had with Eva May, a famous German actress who committed suicide when Mandl wouldn't marry her. Lamarr herself was engaged twice before this marriage. Her first fiancé (Ritter Franz von Hochestetten) killed himself when she broke the engagement because she was more interested in pursuing a career in drama. The same sort of situation (*sans* suicide) occurred between her and Count Blucher von Wahlstatt.

Page 19

Panels 7-9: Mandl did indeed have great difficulty controlling torpedoes, and it seems likely that he would have edited out misses from the infomercials he showed prospective buyers.

Page 20

Panel 5: This scene, and particularly this panel, is pure fiction. At this point in their relationship Lamarr wouldn't have offered her husband her ideas, and there's no evidence that Lamarr was thinking about much besides escape. But Mandl's jealousy, which led to her being at his side night and day, coupled with Lamarr's native intelligence, probably started her thinking about the problem at about this time.

Page 21

Panel 6: Mandl did indeed keep Lamarr under guard and had her followed for much of their marriage. He viewed her more as a possession than a person: Mandl, rifle in hand, burst in on a (mostly) innocuous encounter she had with a nobleman who was kissing her fingers in the Hapsburg Palace. She dove out the window to escape and landed head first in the snow bank. Looking down at her from the window, Mandl simply said "Get her out of the snow…she'll catch her death of a cold."

Page 24

This sequence makes reference to Milton Caniff's Sunday 7/9/39 *Terry and the Pirates* comic strip. Is it coincidence that this classic page from a classic strip came out at roughly the same time as Lamarr made her escape from pre-WWII Europe?

Well, yes.

Page 27

Panel 1: Lamarr escaped to the U.S. on the *Normandie*, a ship with the same name as Pat Ryan's unrequited love in Caniff's *Terry and the Pirates*. This too is a coincidence—I wrote page 24's nod to Caniff before learning this.

Lamarr did indeed get a divorce from Mandl on the charge of desertion! She argued that she was so in love that she couldn't stand his business trips. In fact, she applied to the Holy Rota for an annulment, which was granted thanks in part to pressure put on the church by some of Lamarr's reluctant but influential friends.

Page 29

Panel 9: This line is similar to the famous "Play it again, Sam" in that even though everyone remembers it, it isn't in the movie. (Nor was Lamarr — in *Casablanca*, that is. She turned down the role that Ingrid Bergman made famous.)

Page 30

Panel 1: Gene Markey, though he was her husband for only eight months, has his surname immortalized on Lamarr's patent.

Page 32

Panel 3: Antheil's avant garde piece called "Ballet Méchanique" featured 16 player pianos, two electrically driven airplane propellers, four xylophones, four bass drums, and a siren. It caused quite a sensation, and din.

Page 33

In fairness to the Navy, Lamarr's patent couldn't be used for reasons in addition

to the short-sightedness of military brass. The mechanical device proposed in the patent, though theoretically workable, would have been difficult to construct with enough precision in the 1940s. But by 1962 solid-state technology had caught up with her and frequency-hopping was part of the secure communications systems used during the Cuban Missile Crisis. Today, wireless communications for the Internet and cellular phones depend on the technique. As her son John Loder—who owns a Los Angeles phone store—said, "It's in every other phone system I sell." In 1997, the Electronic Frontier Foundation awarded her its Pioneer Award for "blazing new trails on the electronic frontier."

Page 34

Panel 2: The National Inventor's Council, in place to promote ideas helpful to the war effort, existed until 1974. In its time it generated over 600,000 suggestions for inventions, but only a few became patents.

Page 36

Even at $50,000 a kiss, if you do the math you'll come up with a lot of frogs that didn't turn into princes.

References

Ecstasy and Me: My Life as a Woman, by Hedy Lamarr (NY: Bartholomew House, 1966).

Lamarr has denied writing this, and at the very least it seems unlikely that she wrote all of it. My suspicion is that much of the book comes from conversations with a ghostwriter, who took liberties when filling in details. (Considerable liberties is my guess, especially where descriptions of bedroom antics and passages that purport to be actual psychiatric transcripts are concerned.) Lamarr and the publisher settled out of court.

The Films of Hedy Lamarr, by Christopher Young (Secaucus, NJ: Citadel Press, 1978).

Though its tone lends it more believability than *Ecstasy and Me*, this book is mostly a love-letter from a fan. And like the "autobiography," it makes no mention of her interest in invention.

Bad Boy of Music, by George Antheil (Garden City, NY: Doubleday, 1945).

Like *Ecstasy and Me*, Antheil's stories are too overtly candid (in a conspiratorial "now don't let anybody know I told you this, but…" sense) and his prose style is too breathless to take at face value. But this book appears to be the only source of first hand facts about their meeting and collaboration, and his respect and admiration for Lamarr as a person and an intellect come across as genuine.

The Great Movie Stars, by David Shipman (NY: Hill and Wang, revised edition 1979).

This encyclopedic book on film personalities provided the kernel of the idea for the last scene with Louis B. Mayer and some insights into his character, from which I imagined his and Lamarr's interactions.

"A sultry screen star who didn't just act — she invented," by Elizabeth Weise (The Associated Press, March 9, 1997).

This wire service report appeared in dozens of U.S. newspapers, and gives the basic facts on the history of Lamarr's life and patent.

"Advanced weaponry of the stars," by Hans-Joachim Braun, in *American Heritage*

of Invention & Technology, vol. 12, no. 4, Spring 1997, 10-17.

If you read only one other piece about Lamarr, I would recommend this one. It comes complete with photos, conjecture, narration, and more history than you get from Weise's article. A related article called "Celebrity is the mother of invention" by Travis Brown provides intriguing glimpses of inventors who were famous for things other than their ingenuity. Additional perspectives on Lamarr's invention appear in *Forbes* ("I guess they just take and forget about a person," by Fleming Meeks, vol. 145, no. 10, May 14, 1990, 136-138) and *Scientific American* ("Spread-spectrum radio," by David R. Hughes and Dewayne Hendricks, vol. 278, no. 4, April 1998, 94-96). "Secret Communication System," U.S. Patent #2,292,387 issued to Hedy Kiesler Markey and George Antheil, August 11, 1942.

Though we've attempted to give the gist of the invention in the story, if you want all the details about how to control torpedoes from a distance without your enemies jamming the signal, start here. Lamarr and

Lise Meitner

Meitner's was another life profoundly affected by World War II. Like Lamarr, she too was thwarted by an irrelevant trait she could do nothing about: her Jewish background. Leaving Germany was a hardship for her, but on balance the likely alternatives—execution in a concentration camp or forced labor on nuclear weapons—make exile sound better. She enjoyed more success and certainly more longevity in her field than Lamarr, though, and had a productive and respected career in science that lasted all her life.

Notes

Page 39

Panel 1: Niels Bohr was perhaps the second most famous physicist of his day, eclipsed only by Albert Einstein. Unlike Einstein, though, Bohr enjoyed interacting with students, and he was a mentor to many scientists who later won Nobel Prizes.

Panel 2: James Franck and Gustav Hertz went on to share the Nobel Prize for experimentally demonstrating one of the fundamental ideas behind quantum mechanics: that atoms could absorb energy only in discrete amounts.

Panel 3: Fritz Haber was one of the most famous chemists of his day, and considered a great patriot for his work on chemical weapons during World War I. He was also Jewish, and died in exile in Switzerland after leaving Germany. A few bold scientists defied the Nazis to hold a memorial service in his name.

Page 40

Panel 1: The German economy was devastated by the war. Inflation was so bad that many received their wages daily, some in wheelbarrows, and all rushed to spend the rapidly devalued currency before its worth decreased further the next day…or hour.

Panel 4: It's impossible to summarize Max Planck's contributions to modern physics in a footnote. He was the first to explain

hitherto baffling experimental results with his early attempt at a quantum theory. One of the fundamental constants of the modern theory is now named for him. He also liked foot races.

Page 42

Panels 3-4: Meitner's early experiments were similar to her friends Franck and Hertz's. She (along with Otto Hahn) bombarded atomic nuclei with electrons and then studied what kind of radiation they produced as a result.

Page 43

Panel 2: Meitner and Bohr became good friends, and she visited Bohr's institute in Copenhagen often. They got along well, and he was one of the first people she saw after her exile. There he demonstrated his newest ideas about atomic nuclei, teasing her (Meitner's approach to physics was less playful than Bohr's) by introducing his model using billiard balls he'd had manufactured especially for this purpose.

Panels 4-5: Beta rays are, for all practical purposes, just like the electrons orbiting the atom's nucleus. Magnets deflect charged particles, so you can tell how energetic an electron is by how much a magnet bends its path as it speeds by. Think about driving a car (electron) over a pothole (magnet): If you're going slow your wheel will dip into it and you'll feel quite a jolt. The faster you go, the less the pothole will deflect the path of your tire, and the less you'll bounce.

Page 44

Panel 2: Atoms are made up of small electrons, which surround a nucleus made of much larger (~2000 times as massive as electrons) protons and neutrons. Radioactive atoms decay by emitting particles (protons, neutrons, electrons, and photons) from their nuclei, where the protons and neutrons are. If you have a bunch of these atoms, their "half-life" is the time in which half of the atoms emit their particles.

Panel 6: Ida Noddack and Irene Curie both had theories about what would happen if you bombarded heavy elements like uranium with neutrons. Their ideas, though wrong in important ways, were very close to Meitner's correct interpretation (fission).

Page 45

Panel 2: An alpha particle is made up of two neutrons and two protons, so it's roughly four times as massive as a neutron. If you think of a nucleus as a big pile of bowling balls (alpha particles), then Meitner's skepticism makes sense: You wouldn't expect that lobbing a softball (a slow neutron) into this pile of bowling balls would knock two out!

Panel 6: Meitner's Jewish background made staying in Germany impossible. Though she held on longer than many, she eventually accepted that she'd have to leave. (If Haber wasn't safe from persecution, how could she expect to be?) By the time she got out it was difficult for even someone as respected as she to find a position abroad—there were simply more refugees than jobs. So though her appointment in Stockholm wasn't ideal, in many ways she was fortunate to get it.

Panel 7: Surface mail moved a *lot* faster in those days. Letters got delivered daily between Stockholm and Berlin, which even in this era of email doesn't sound too bad.

Page 46

Panel 5: An isotope is an element with an atypical number of neutrons in its nucleus. Because chemical properties of atoms are determined by their charged particles (the protons and electrons), isotopes are chemically identical to their parents. For instance, we mentioned earlier that hydrogen usually has no neutrons. Deuterium is an isotope of hydrogen with one neutron. Water made with this isotope is called "heavy water", and in most respects it behaves chemically just like regular old H_2O.

Panel 6: Remember when we said that knocking off alpha particles with slow neutrons is like knocking out bowling balls with softballs? Well, a barium atom is much larger than an alpha particle. So this seems even more unlikely. But that's only if we assume a "pile of bowling balls" model of the nucleus…

Panel 8: …a model that Bohr (and Meitner) didn't think told the whole story. When they thought of large nuclei as having some of the properties of a drop of water—specifically, a wobbly and unstable nature balanced by forces that had a cumulative effect a lot like surface tension—they could more easily picture it breaking apart. And that's what Meitner and Frisch did!

Page 47

Panel 5: It's tough to explain why the sum of the masses of the two pieces of a uranium nucleus is less than the nucleus it came from in a short footnote, so let's trust that Lise and Otto know what they're talking about here.

Panel 8: Both Meitner and Frisch understood the physical implications of their calculations almost immediately.

Page 48

Panels 6-7: Bohr loved a good solution even when he didn't think of it himself, and the more visual (and less buried in equations) that solution, the better. He would often say "You're not thinking; you're just being logical!" if his colleagues got too abstract and mathematical with their arguments.

References

What Little I Remember, by Otto Frisch (London: Cambridge University Press, 1979).

Frisch actually remembered plenty, and writes about his work with many famous physicists with verve and humor.

"Looking back," by Lise Meitner, in *Bulletin of the Atomic Scientists*, vol. 20, no. 11, November 1964, 2-7.

Meitner's good-natured recollections in this short article prompted the humorous touches in this story. Though disappointed (and perhaps briefly embittered) by the Nobel Prize committee's decision to award their prize for the discovery of fission only to Hahn and Strassman, she didn't let those feelings dominate her life.

Lise Meitner: A Life in Physics, (Berkeley: University of California Press, 1996); "Lise Meitner in Sweden 1938-1960: Exile from physics," in *American Journal of Physics*, vol. 62, no. 8, August 1994, 695-701; "A Nobel tale of postwar injustice," in *Physics Today*, vol. 50, no. 9, September 1997, 26-32; and "Lise Meitner and the discovery of nuclear fission," in *Scientific American*, vol. 278, no. 1, 80-85.

Ruth Lewin Sime wrote all of the above (working with Elisabeth Crawford and Mark Walker in the *Physics Today* article), and they
combine to form the most comprehensive look at Meitner to date, and though heav-

ily footnoted, they are readable as well. Though her perspective sometimes focuses on the negative (she is particularly hard on Otto Hahn and his post-war posture), Sime does a thorough and convincing job of presenting the case that Meitner was treated poorly by both Hahn and the Nobel Prize committees.

Lise Meitner, Atomic Pioneer, by Deborah Crawford (NY: Crown Publishers, 1969).

Crawford aims her book at less scholarly, and certainly younger, readers. Because of this, she concentrates more on fictitious dialogue (not that I can fault her for that, of course!) and a lightweight and optimistic take on Meitner's career and relationship with Otto Hahn. Still, this is an engaging introduction, and includes a transcript of a radio conversation Meitner had with Eleanor Roosevelt just after the first atomic bomb fell.

Otto Hahn: My Life, by Otto Hahn, translated by Ernst Kaiser and Eithne Wilkins (NY: Herder and Herder, 1970); and *Otto*

ROSALIND FRANKLIN

"Never attribute to malice what you can explain with incompetence." An old saying, and often true. Nobody here was incompetent, though, including the Nobel Prize committee—off camera but almost always in many of our characters's peripheral vision. Nor was anyone malicious, actually. All merely looked for and saw different things in the data and each other. So how can we explain Rosalind Franklin's comparative lack of fame for her role in the discovery of DNA's structure? She earned better, both in terms of respect from her colleagues during their crucial work and during her lifetime. Like Adrienne Weill says at the end, we'll never know for sure whether this was because of her gender or

Notes

Page 51

Adrienne Weill ties together the beginning, middle, and end of this story and this book in more ways than one. She was not only a close friend and correspondent of Franklin's, but also one of Marie Curie's coworkers. A noted French-Jewish scientist, she was instrumental in getting Franklin her job studying holes in coal in Paris.

Page 52

Panel 1: According to many accounts, this analysis is just the sort of thing Franklin was likely to do.

Page 53

Panel 1: The lab was a mixture of physicists and biologists—an experiment in biophysics arranged by John T. Randall, a famous physicist and co-inventor of radar.

Panel 3: Though Randall (working in the role of an administrator here, so he's no longer overly concerned with the science or personalities involved) seems to dismiss Gosling's work, it was first rate given his equipment. The whole purpose of hiring Franklin was to take things to the next level, and Gosling bore her no animosity. He became her friend as well as her colleague.

Page 54

Panel 3: Franklin did seminal work on coal, and later on the tobacco mosaic virus. If she'd had no role in the discovery of DNA she would still be remembered today (by scientists, at least) for this crucial research.

Page 58

This page is told from Maurice Wilkins' perspective, and is the first alternate take on Franklin as a person and (less so) as a scientist. Wilkins and Franklin got off on the wrong foot immediately, in part because of a misunderstanding regarding the terms of her employment, and in part because they simply had incompatible personalities. Their relationship never moved beyond this, and most of the time didn't even reach a level of professional courtesy. They simply didn't get along. This may have been the main reason why her contributions to the discovery of DNA's structure were given short shrift.

Pages 59-60

Franklin's decision to focus on "dry" DNA may have been an important factor in her lack of involvement in the subsequent discovery. Though solving dry DNA's structure may have been the harder problem to solve, it wasn't necessarily the *right* problem to solve. DNA in action exists in its wet form, after all. Why did she do it, then? We'll never know, but as Francis Crick has put it: "Just as important as having ideas is getting rid of them." Franklin would have done well to get rid of this one.

In her notes to herself she acknowledged "evidence for [a] spiral structure" but was unwilling to talk about a helical structure with Wilkins. She concluded that there was a "big helix or several chains, phosphates on the outside, phosphate-phosphate bonds, disrupted by water … The results suggest helical structures … capable of absorbing water in large quantities [of eight molecules per nucleotide] …"

Page 61

Panel 1: This scene, completely imagined, is intended to make the point that the tea room Boy's Club was so ingrained and natural to the male scientists that it probably took even a sensitive and guileless fellow like Gosling a while to notice.

Page 62

This section, told from James Watson's perspective, focuses on his initial failure to pay attention to, learn from, and do more than stereotype Rosalind Franklin (physically and intellectually) during their first encounter. Though he quite candidly acknowledged most of these (and other) mistakes in his famous book *The Double Helix*, he does so in a rather offhand "aren't I a charming and brutally honest fellow anyway" manner. Because his book is so popular, and tells such a compelling story, it propagated a misleading view of Franklin and her work for years. Regarding panel 8, Watson was indeed a good tennis player.

Page 66

Francis Crick, Watson's partner in writing their famous paper describing the structure of DNA, became closer to Franklin in her later years. So, unlike in the Watson section above, we show Crick seeing her much more as she is. In fact, he's the closest we come in the story to a fair witness, other than Adrienne Weill (who you may have forgotten about by now). Sir Lawrence Bragg is another famous physicist who,

like Randall, ended up working in biology after World War II.

Page 68

Panels 3-5: Franklin did write a memo to this effect and deliver it to her lab partners.

Page 70

This section, told from Watson's and Wilkins' perspectives, depicts the OK Corral-esque showdown between Franklin and Watson, which Watson made into one of the high points of his book *The Double Helix*. I hope this reads as a bit of a farce here, since a violent confrontation between the two was pretty much unthinkable according to both Wilkins and Crick. Watson clearly overreacted at the time and dramatized it in his book, presumably for the sake of an exciting anecdote.

Page 72

Panel 7: Wilkins: "DNA, you know, is Midas' gold. Everybody who touches it goes mad."

Panel 9: Watson and the rest of the audience found *Ecstasy* disappointing: "Before the film was half over we joined the violent booing of the disgusted undergraduates as the dubbed voices uttered words of uncontrolled passion."

Page 73

Panels 4-6: Though it looked easier (or at least more fun) than what Franklin was doing, the model building Watson and Crick did here required a great deal of intellectual effort. Their work was rigorous and scientific — and successful.

Francis Crick's thoughts on her (and their) approach says a lot about how, and why, science gets done the way it does: "I believe that one reason for [her reluctance to build or use physical models], apart from the marked difference in temperament, was because she felt that a woman must show herself to be fully professional. Jim had no such anxieties about his abilities. He just wanted the answer, and whether he got it by sound methods or flashy ones did not bother him one bit. All he wanted was to get it *as quickly as possible*."

Page 75

Francis Crick narrates the final section not told by Adrienne Weill, in large part because he, more than the other two Nobel Prize winners, seems to have had a mature, truly professional, and personal relationship with Franklin. He and his wife Odelle eventually became good friends with Franklin, and helped her (and put her up in their home) during one of the brief convalescences preceding Franklin's death from cancer.

References

The Double Helix, by James D. Watson (originally published in 1968, but seek out the Norton Critical Edition edited by Gunther Stent, NY: W.W. Norton & Company, 1980).

Start here, but don't stop with what Watson accurately calls "A personal account of the discovery of the structure of DNA." If it were mine to subtitle, I would change that to "A very personal account…" This book caused an uproar in both its draft and published forms, and may have been the main (though inadvertent) reason why many began to pay attention to Franklin's role in the discovery. It's fascinating.

Rosalind Franklin & DNA, by Anne Sayre

(NY: W.W. Norton & Company, 1975).

Clearly a reaction to Watson's book and an important and essential source. I couldn't put a finger on why this left a bad taste in my mouth until reading Vivian Gornick's description of it in *Women in Science* (NY: Touchstone, 1990 edition): "…its tone is so defensive the reader comes to distrust its account and interpretation of the crucial events it is describing." An important book, but because of its overt agenda and tendency towards speculation about motives, it doesn't read as any more objective than Watson's.

Rosalind Franklin, the Dark Lady of DNA, by Brenda Maddox (NY: HarperCollins, 2002).

This book presents a much more balanced account of Rosalind Franklin than Sayres'. If you read only one book about Rosalind Franklin, make it this one.

What Mad Pursuit, by Francis Crick (NY: Basic Books, 1988).

Not at all a reaction to Watson's book (though its subtitle—"A personal view of scientific discovery"—is similar enough to make the idea plausible), this is a more measured and philosophical look at how one scientist approaches science. It's by no means dry, however, and offers lively insights into Crick's views of how science is best done. It also recounts the making of a BBC docudrama (which I've still not seen) called *Life Story*, about the quest for DNA's structure and mentions an unsuccessful attempt at a Hollywood movie, for which the script failed to find a backer. Just as well that it didn't appear and I didn't see it either, since Crick specifically mentions that he and Watson retained rights to any comic book adaptation!

"An interview with Nobel Laureate Maurice Wilkins," by Stephanie Johnson and Thomas R. Merten, in *The American Biology Teacher*, vol. 51, no. 3, March 1989, 151-153.

This interview typifies for me how little Wilkins cares to reveal about himself. Perhaps I didn't look hard enough, but I found very few sources outside of Judson's book (below) that gave a sense of Wilkins either as a flesh-and-blood person or scientist. Interestingly, for all their enmity, Wilkins is the only one of the three Nobel Prize winners who mentioned Franklin in his Nobel lecture. *The World of Physics*, by Jefferson Hane Weaver (Vol. 2, NY: Simon & Schuster, 1987) reprints part of his and Crick's lectures.

"Molecular structure of nucleic acids: A structure for deoxyribose nucleic acid," by James Watson and Francis Crick, in *Nature*, vol. 171, no. 4356, April 25, 1953, 737-738.

A surprisingly accessible paper, even for a lay audience, considering its contents earned them a Nobel Prize.

The Eighth Day of Creation, by Horace Freeland Judson (NY: Simon and Schuster, 1979).

Judson's detailed but accessible account of the history of biochemistry draws on both published accounts and extensive interviews with the principals involved. Part I in particular covers similar ground to Olby and Watson's books, but from a different (and in the case of Watson, at least, a more balanced and rigorous) perspective.

"The legend of Rosalind Franklin", by Horace Freeland Judson, in *Science Digest*, vol. 94, no. 1, January 1986, 56-59; 78-83.

Judson apparently wrote this condensed version of *The Eighth Day of Creation*, with its emphasis on the question of Franklin's contribution, at least in part as a reaction to the books by Sayre and Gornick. He goes to great lengths and presents much evidence (drawing on interviews with her fellow scientists) to refute the idea that Franklin's isolation was a result of sexual discrimination.

The Path to the Double Helix, by Robert Olby (NY: Dover Publications, 1994).

This book presents a thorough, detailed scientific history of the path to the double helix. The players in the story you just read don't even appear until the book is well past the halfway point! It offers little in terms of the personalities involved, which played a key part in who made the final discovery, but does feature many direct quotes by Crick, Watson, Wilkins, and Bragg.

Finally, Wilkins, Watson, and Crick all cite Erwin Schrödinger's *What is Life?* (Lon-

BARBARA McCLINTOCK

I hope this book (and all the other G.T. Labs books) shows that the community of scientists is made up of honest-to-goodness people. As such, scientists can succumb to trends. Perhaps not as often or as extreme as the ones we see in pop music and *haute couture*, but there's hip science and there's unfashionable science. McClintock resisted the fad of molecular biology (which began with the discovery of DNA's structure and continues to this day), stuck with her research on corn genetics when other organisms were more popular, and eventually won the Nobel Prize for her discoveries.

Talking about her life's work, McClintock once said: "You may think [chromosomes] are small when I show you pictures of them. But when you look at them, they get bigger and bigger and bigger." This applies to her life as well. She considered herself an anomaly, shunned the idea of being a role model for others, and was "plainly miserable" with all the attention she began to receive in the 1970s. But though her life is certainly unique,

Notes

Page 81

Panel 1: Your basic building block of life, about which McClintock said: "Well, you know, when I look at a cell [in a microscope], I get down in that cell and look around." This is in fact a corn cell, but not of the type she would usually look at.

Panel 3: McClintock studied corn throughout her scientific career, staying out of the more *chic* areas of research in molecular biology. Prompted by the discovery of DNA's structure, most of her colleagues began to focus on the more easily quantified chromosome in smaller organisms like *E. coli*. McClintock stuck with the far more elusive genes, in the vastly more complicated corn. Her ability to grasp this complexity where others couldn't led many to call her a mystic. She didn't like that, but was probably too modest to say that what others called mysticism was simply smarter, more painstaking, and more dedicated science. She wasn't so enamored with science that she couldn't speak at least a little mystically, though: "[The scientific method] gives us relationships which are useful, valid, and technically marvelous… [It's] lots of fun…but you don't get the truth. Things are much more marvelous than the scientific

method allows us to conceive."

Page 84

We've left the class and the test McClintock found so engrossing ambiguous, so you probably assumed it was biology that enthralled her to the point of forgetting her own name. In fact, it was geology. But the rest of this anecdote is true. She would later say the following about scientific work: "As you look at these things, they become part of you. And you forget yourself. The main thing about it is you forget yourself."

Page 85

Panel 7: Wait…there is no panel 7 on page 85! After graduating with a Ph.D. in 1927, she traveled extensively across the U.S. At the time, geneticists were either breeders (working in the field to create new strains of plants) or people who worked on chromosomes. The two never mixed. Except in the person of McClintock, who because of this (and because she was a woman) never found a position that suited her, or a faculty that would accept her. She also traveled briefly to Germany on a Guggenheim Fellowship in 1933, but returned quickly, shaken by the political situation there.

Page 87

Panel 4: "Animals can walk around, but plants have to stay still to do the same things... For instance, if you pinch a leaf of a plant you set off electric pulses. You can't touch [one] without setting off an electric pulse... There is no question that plants have all kinds of sensitivities."

Pages 88-89

McClintock slowly convinced her colleagues of the correctness of her theories, in part by sheer force of will. It took most of them a long time to get it, though, and confirming results by Monod and Jacob proved essential for her work's acceptance. "The logic was compelling. The logic made itself, the logic was it. What's compelling in these cases is that the problem is sharp and clear. The problem is not something that's ordinary, but it fits into the whole picture, and you begin to look at it as a whole... It isn't just a stage of this, or that. It's what goes on in the whole cycle. So you get a feeling for the whole situation of which this is [only] a component part."

Page 89

Panel 6: It wasn't easy to find pictures of McClintock in a dress. In fact, the one taken at the Nobel Prize ceremony is the only one I've seen.

Page 90

She continued to work alone after receiving the Nobel. In fact, her colleagues said she "was plainly miserable" with all the attention. And James Watson (Jim in the previous story) did indeed play ball near her corn field, and later became Cold Spring Harbor's successful and respected director.

References

A Feeling for the Organism, by Evelyn Fox Keller (NY: W.H. Freeman, 1983).

Though McClintock stopped cooperating with Keller before she had finished the book, it still reads as an authoritative account of her work.

The Dynamic Genome, edited by Nina Feder-

off and David Botstein (Plainview, NY: Cold Spring Harbor Laboratory Press, 1992).

Definitive and surprisingly accessible to all readers, this collection of scientific papers, reminiscences, and original articles by McClintock and others will give you a well-rounded picture of her as both a person and a scientist.

"Two genes, no enzyme: A second look at Barbara McClintock and the 1951 Cold Spring Harbor Symposium," by Nathaniel C. Comfort, in *Genetics*, vol. 140, no. 4, August 1995, 1161-1166.

An interesting perspective on why McClintock's first "jumping gene" talk didn't connect with the vast majority of her audience, from one of those audience members. (Who "got it" sooner than many.)

"A naturalist of the genome," by Roger Lewin, in *Science*, vol. 222, no. 4622, October 28, 1983, 402-404; and "Barbara McClintock (June 16, 1902 - September 2, 1992)," by Nina Federoff, in *Genetics*, vol. 136, no. 1, January 1994, 1-10.

If *The Dynamic Genome* gets too technical (it did for me), try these summaries of

Biruté Galdikas

We aged Dr. Galdikas throughout the story because her work continues to this day, and the story we've told here gives only a glimpse of the complex nature of a field researcher and her life. Compressing more than 20 years of work into roughly 20 pages of comics means we had to leave out details and background information.

That scientific and conservation work is by no means finished. Fortunately, as Galdikas says, "Orangutans are what conservationists call 'charismatic megafauna': large, extremely appealing animals." In other words, they're ideal tourist attractions. In part because of this, volunteers, many from Earthwatch, have helped her gather the data and preserve the orangutans (who are threatened by poachers) and their fragile habitat (threatened by loggers, farmers, and the wildfires that spread easily because of their activities).

If you would like to learn more about this important work you can contact the Orangutan Foundation International by calling 1-800-ORANGUTAN, messaging *ofi@orangutan.org*, visiting their website at *http://www.orangutan.org/*, or by writing

Orangutan Foundation International
4201 Wilshire Boulevard, Suite 407
Los Angeles, CA 90010
USA

References

Orangutan Adaptation at Tanjung Puting Reserve, Central Borneo, by Biruté M.F. Galdikas (Ph.D. thesis, University of California, Los Angeles, 1978); and *Reflections of Eden: My Years with the Orangutans of Borneo*, by Biruté M.F. Galdikas (Boston: Little, Brown and Company, 1995).

If all dissertations were this readable scientists would probably have an easier time getting grant funding. Her book offers

even more accessible prose and I found its personal focus on individual orangutans and stories engrossing and entertaining.

"Orangutans, Indonesia's 'People of the forest'," by Biruté Galdikas with photographs by Rod Brindamour, in *National Geographic*, vol. 148, no. 4, October 1975, 444-473; "Living with the great orange apes," by Biruté Galdikas and Rod Brindamour, in *National Geographic*, vol. 157, no. 6, June 1980, 830-853; and "Orangutans in the wild," by Cheryl Knott with photographs by Tim Laman, in *National Geographic*, vol. 194, no. 2, August 1998, 30-57.

The two articles by Galdikas don't add a great deal to her thesis or book. They're shorter, though. And like Knott's article (which by contrast presents a mostly analytical/hard data approach to orangutan research) they also feature many more pictures, all of the consistently high quality *National Geographic* is famous for.

Watching the Wild Apes, by Bettyann Kevles (NY: E.P. Dutton, 1976) and *Walking with the Great Apes*, by Sy Montgomery (Boston: Houghton Mifflin, 1991).

Kevles' book planted the seed of the idea for presenting a fictionalized day in the life of a researcher, and provides a fine introduction to all three of Louis Leakey's protégés (Galdikas, Dian Fossey, and Jane Goodall). As for Montgomery, after reading the introduction I was prepared to dislike the rest, anticipating an "Aren't they wonderful because they're women?" tone to mar the book. Fortunately, the conclusion I jumped to was wrong. Hers isn't the objective journalism that people (especially scientists) pretend exists, but is instead intelligent advocacy writing.

Any public figure as internationally prominent as Biruté Galdikas will inevitably receive some bad press. Two articles ("Monkey business in Borneo," by Simon Freeman, in *The Guardian*, January 4, 1994, section G2T, 14; and "The jungle took her," by Linda Spalding, in *Outdoor*, vol. 23, no. 5, May 1998, 78-90; 189-191) in more than twenty years isn't too bad, though. These articles give detailed, negative, but (especially in the case of Spalding's) ultimately sympathetic descriptions of Galdikas' recent struggles and conflicts with both the scientific community and governmental agencies. They paint a picture of conservation work that offers no clear-cut heroes or villains. As Dr. Galdikas pointed out to me, though, *The Guardian* wrote a follow-up article ("Jungle fever," by Jan Moir, February 15, 1995, 2) that presents a more balanced approach.

Finally, if you like the story's pictures more than its words, have a look at *Orangutan Odyssey* by Biruté Galdikas and Nancy Briggs, with photographs by Karl Ammann (NY: Harry N. Abrams, 1999), *The Nature of Borneo*, by Steven Yates (NY: Facts on File, 1992) or seek out the National Geographic videos *Search for the Great Apes* (Executive Producer Dennis Kane, 1975) and *Creatures*

Epilogue: Marie Curie

I hope that this epilogue, though at first glance sad, instead reads as ironic in light of the quotes reproduced in the prologue section. Like many of the others in this book, Marie Curie found that even though she disdained it, fame had many rewards, and that she could use her position to help others. Unfortunately, and also like many of the scientists featured here, she also found that fame came at a high personal price.

References

Marie Curie, by Robert Reid (London: William Collins Sons & Co. Ltd., 1974).

This provided the source and context for the title of the book, which appears here in the epilogue as well. The complete letter appears (along with many others to and from her daughter Irene) in *Correspondence; choix de lettres, 1905-1934 de Marie et Irène Curie. Présentation par Gillette Ziegler*, by Marie Curie (Paris: Èditeurs Francais Réunis, 1974).

Emmy Noether

Hermann Weyl, a noted mathematician in his own right, put it best: "She was not clay, pressed by the artistic hands of God into a harmonious form, but rather a chunk of human primary rock…" As for the German on the back cover, Mist = crap, and Formelngestrüpp = a jungle of formulas—words Noether often used to describe her doctoral dissertation.

References

Women and Numbers, by Teri Perl (San Carlos, CA: Wide World Publishing/Tetra, 1993).

A nifty book for teachers, this all-ages illustrated book contains biographical anecdotes, classroom activities, and plenty of mathematical games.

Emmy Noether: A Tribute to Her Life and Work, edited by J.W. Brewer and M.K. Smith (NY: Marcel Dekker, 1981); and *Emmy Noether, 1882-1935*, by Auguste Dick (Boston, MA: Birkhäuser, 1981).

For a brief biography either book will serve, though Brewer and Smith give a