The Jesus Tomb Math

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1 An Improbable Challenge

Probability and statistics lie at the heart of the startling claim by James Cameron, Simcha Jacobovici, and others that the Talpiot Tomb, discovered twenty-five years ago outside Jerusalem, is the tomb of the New Testament Jesus. Specifically, proponents of this view have put forward a number—1 in 600—as the probability that the Talpiot Tomb could be other than the tomb of Jesus. Thus conversely, it is supposed to be highly probable—with probability 599 in 600—that this is Jesus' tomb. Thus, one is informed on the Jesus Family Tomb website: "After listening to filmmaker Simcha Jacobovici explain the so-called 'Jesus equation', you'll realize just how *unlikely* it is that this *isn't*, in fact, his tomb."[1]

Readers of Simcha Jacobovici and Charles Pellegrino's *The Jesus Family Tomb: The Discovery, the Investigation, and the Evidence That Could Change History* and viewers of Discovery Channel's documentary *The Lost Tomb of Jesus* are given the impression that to deny that the Talpiot Tomb is the tomb of Jesus is to renounce the rigors of mathematical thinking and to embrace irrationality. Thus Jacobovici writes: "At the end of the day, if I were a betting man and you let me be the house, and you could assure me that each time a player spun my wheel the odds were 600 to one in my favor, I would not hesitate to play."[2]

Accordingly, to reject the claim that the Talpiot tomb belongs to the New Testament Jesus is like stirring at random a pot containing 599 white balls and one black ball and then betting that the selected ball should be black—clearly, the smart money is on white. But where does this 1 in 600 probability come from? And how are we to interpret it? Because probabilities can be difficult to assign and even more difficult to interpret, Simcha Jacobovici, the driving force behind the recent effort to make the Talpiot Tomb the greatest archeological find in history, therefore enlisted a professional statistician to perform the relevant probability calculations and then to interpret them: University of Toronto statistician Andrey Feuerverger.

In this paper, we examine both the logic by which Feuerverger came to his improbability of 1 in 600 and then the logic by which Jacobovici *et al.* concluded that the Talpiot Tomb must in all likelihood be Jesus' tomb. Although Feuerverger's approach contains some valid insights, it also commits some fatal oversights. In cleaning up Feuerverger's math, we find that the improbabilities are not nearly as bad as he makes out. Indeed, we find that a significant number of families in Palestine at the time of Jesus were likely to have the pattern of names found in the Talpiot tomb.

A corrected version of Feuerverger's model using reasonable estimates of the probabilities for the New Testament names found in the Talpiot tomb shows that there were likely to be as many 154 Jewish families living in Palestine at the time with the pattern of names found in the Talpiot tomb. On the "Jesus Family Tomb" people's reckoning, this would yield a probability of 153 in 154 that the Talpiot Tomb is *not* the tomb of Jesus. And even if we go with the "Jesus Family Tomb" people's smaller probability estimates for the New Testament names found in the Talpiot tomb, a Bayesian analysis that takes into account additional evidence not considered by Feuerverger increases this probability close to one.

In consequence, Jacobovici *et al.* have no rational basis for identifying the Talpiot Tomb with that of Jesus. In fact, the most reasonable inference—leaving aside any presuppositions about the infallibility of the Bible or the truth of Christianity—is that this most probably is *not* Jesus' tomb.

2 Reality Check

As professionals in the mathematical and engineering sciences, we had misgivings about the "Jesus Family Tomb" story from the start. Investigator bias is always a danger in analyzing data. People, and we include ourselves here, are notorious for wanting to see their wishes fulfilled. For this reason, science imposes constraints on researchers so that their biases do not cloud their conclusions. These constraints take the form of prescribed methods for properly conducting research—in other words, they prescribe ways scientists are supposed conduct their research to keep them out of trouble.

Take the testing of new drugs. Such studies are supposed to be double-blind, meaning that neither the subject receiving the new experimental drug nor the experimenter administering it and judging its effectiveness is supposed to know whether the actual drug or a placebo was administered. Only then can the drug's effectiveness be evaluated fairly. Otherwise, the patient or experimenter or both, having prior expectations about the drug's effectiveness, may rate the patient's performance in line with those expectations rather than objectively. Ideally, if proper research methods are employed, it should be possible for any outside observer to look at the data and come to roughly the same conclusion.

With the "Jesus Family Tomb" people, however, we are dealing with no such controls. Here we have a group of people who stand to profit (and indeed have already profited) from sensationalizing the Talpiot Tomb as the tomb of Jesus. Moreover, they are eager to state and advertise their conclusions before the hard work of properly analyzing the data is done. Andrey Feuerverger, on whose probability calculations their case rests, admits that this work has yet to be properly done and vetted. On his academic website, addressed to “Dear Statistical Colleagues,” he writes: “A detailed paper is being prepared and hopefully will undergo timely peer review; if successful in the refereeing process it will be made available.”[3] Such an admission hardly inspires confidence given the extravagant claims being made on the basis of Feuerverger’s work. Not only has the rigorous statistical work not been properly vetted; it is still in the process of preparation.

3 Why Even Think That This Might Be Jesus’ Tomb?

A Christian who believes that Jesus rose from the dead and therefore has no remains to place in a tomb would naturally dismiss the “Jesus Family Tomb” story out of hand. But why should anyone without such a prior faith commitment accept the Talpiot Tomb as the final resting place of Jesus? The Talpiot Tomb contains ten ossuaries, or chests with bones. Such tombs with ossuaries were common in Palestine during about a 100-year window, beginning the middle of the first century BC and ending abruptly with the fall of Jerusalem in 70 AD.

In the Talpiot Tomb, four ossuaries have no names inscribed on them and two have names with no obvious connection to Jesus’ family: Matya (a variant of Matthew) and Yehuda bar Yeshua (Judah son of Jesus). Indeed, the Matthew of the New Testament, also known as Levi, is never portrayed as part of Jesus’ family. Moreover, the New Testament gives no indication that Jesus was married, much less had a son. Accordingly, the Jesus Family Tomb people assign no statistical weight to these two names.

That leaves four ossuaries with names corresponding to Jesus’ circle of family and friends as given in the New Testament. Of these, the following three were inscribed in the Hebrew script: Yeshua bar Yehosef (Jesus son of Joseph), Marya (a variant of Mary that leaves off the traditional “m” ending of the Hebrew Miriam or Mariam), and Yose (a short form of Joseph, used in Mark 6:3 to refer to one of Jesus’ brothers). The other name, inscribed in Greek, is Mariamne (a Greek variant of Mary, transliterated this way by the “Jesus Family Tomb” people[4]). The first three names can indisputably be placed in Jesus’ family. The Jesus Family Tomb people regard the fourth as signifying Mary Magdalene, whom, on the basis of certain apocryphal writings, they think to be the wife of Jesus. According to them, these four names are so specific as to leave no option but that this is the tomb of the New Testament Jesus.

To see what’s at stake, Simcha Jacobovici asks us to imagine a large football stadium containing the inhabitants of Jerusalem at the time of Jesus (Jacobovici estimates that there were 80,000 people living in Jerusalem at the time). He then imagines asking those present in the stadium to play what may be called a “specification game.” Jacobovici’s specification game is similar to the “game of 20 questions,” in which one has up to 20 questions to narrow a field of possibilities to identify some unknown item of interest.

In Jacobovici’s specification game, we imagine the stadium announcer running through the names in the Talpiot tomb that correspond to known names in Jesus’ circle of family and friends. The announcer starts by asking all persons named Yeshua bar Yehosef

(Jesus son of Joseph) to stand. Next he asks those with a mother named Marya to continue standing and the rest to sit down. Next he asks only those with a brother named Yose to continue standing. Finally, he asks those with a wife named Mariamne to remain standing. As each name is given, it further specifies, and therefore narrows, the number of people in the stadium with the given pattern of family names.

In general, when describing an object, one may *underspecify*, *uniquely specify*, or *overspecify* it. In underspecifying it, one identifies a class of objects that contains the object in question but also contains other objects. For instance, the description "American presidents" underspecifies Bill Clinton since the class of objects it identifies contains other presidents as well. On the other hand, the description "the 42nd American president" uniquely specifies Bill Clinton since it identifies him and only him. Finally, the description "the 42nd American president whom Congress did not impeach" is overly specific since no object answers to it.

According to Jacobovici, with only 80,000 people in the stadium, at most one person would likely be left standing at the end of the game, namely, the New Testament Jesus. The pattern of names given by the announcer is therefore supposed to uniquely specify Jesus. Jacobovici's point is that just as this specification of names would uniquely identify someone in the stadium, so would finding them in a tomb of ossuaries.[5]

Now, it needs to be admitted from the outset that Jacobovici's specification game could, given enough of the right names, uniquely specify the family of the New Testament Jesus. Suppose, for instance, we found a tomb whose ossuaries included the following inscriptions (note that the last four are the names of Jesus' brothers as given in Mark 6:3):

- Jesus son of Joseph and Mary
- Joseph the father of Jesus
- Mary the mother of Jesus
- Mary of Magdala
- James the brother of Jesus and son of Joseph
- Joses the brother of Jesus and son of Joseph
- Juda the brother of Jesus and son of Joseph
- Simon the brother of Jesus and son of Joseph

In this case, the pattern of inscriptions would uniquely specify the family of the New Testament Jesus. Indeed, unless the tomb inscriptions were deliberately faked, it would be inescapable that here was the family tomb of the New Testament Jesus.

On the other hand, if we had a tomb whose only inscription was "Jesus the brother of Simon," it would be quite a stretch to claim that here was the family tomb of the New Testament Jesus. Jesus and Simon were exceedingly common names in New Testament times (Simon was the most common of all the Jewish men's names at the time, accounting for more than ten percent). Thus, there would have been many men in Jerusalem, to say nothing of ancient Palestine, named Jesus with a brother named Simon. In Jacobovici's football stadium analogy, if we asked only those persons named Jesus with a brother named Simon to stand, lots of persons in the stadium would be standing. The inscription "Jesus the brother of Simon," would therefore underspecify the family of the New Testament Jesus.

The pattern of names in the Talpiot tomb clearly provides more specificity than "Jesus the brother of Simon" but less specificity than the combination of eight names given above. The key question before us is whether the pattern of names in the Talpiot tomb underspecifies or uniquely specifies the family of the New Testament Jesus. Jacobovici and his colleagues claim that it uniquely specifies the family of Jesus. To make their case, they put forward what they call "the Jesus equation." We turn to that equation next.

4 The Jesus Equation

Even though the "Jesus Family Tomb" people frequently refer to "the Jesus equation," in fact they do not write out an actual equation. What they do is take various probabilities and correction factors, and then multiply them together to form the probability that the pattern of names "found in the Talpiot tomb could have belonged to a different family than the one described in the New Testament."[6] Implicit in this calculation, however, is an equation that is easy to reconstruct. Accordingly, if they had written out "the Jesus equation," it would look as follows:

$$p = p_1 \times p_2 \times p_3 \times p_4 \times c_1 \times c_2 \times c_3.$$

Here p is the purported 1-in-600 probability that the Talpiot tomb could by chance be other than the tomb of Jesus, p_1 to p_4 are probabilities associated with names found in the Talpiot tomb, and c_1 to c_3 are correction factors that adjust these raw probabilities.

To determine the probabilities p_1 to p_4, Andrey Feuerverger, the lead statistician for the "Jesus Family Tomb" people, starts with the names mentioned in the Talpiot tomb that correspond to New Testament names known or suspected to belong to Jesus' family. These are Yeshua bar Yehosef, Mariamne, Marya, and Yose. Next, they determine the relative frequencies of these names in light of Tal Ilan's *Lexicon of Jewish Names in Late Antiquity*.[7] Ilan lists all the occurrences of Jewish names that archeologists and historians have discovered and can place around the time of the New Testament. The relative frequencies are as follows:

Yeshua: 103/2,509
Yehosef: 231/2,509
Mariamne: 1/317
Marya: 26/317
Yose: 9/2,509

Note that all the denominators here are either 2,509 or 317. That's because in Ilan's lexicon, only a total of 2,509 men and 317 women are listed. Note also that all of these names are either very common or variants of very common names. Among male names, Yeshua (Jesus) has a freqency of 4 percent. Yehosef (Joseph) has a frequency of 9 percent. Yose is a variant of Yehosef. The most common male name is Simon/Simeon, with a frequency of around 10 percent. Mariamne and Marya are variants of Mary. In Ilan's lexicon, variants of Mary account for a total of 80 out of the 317 female names—that's more than 25 percent.

Feuerverger treats these relative frequencies as probabilities, making the following adjustments: to get the relative frequency for the compound name Yeshua bar Yehosef (Jesus son of Joseph), he multiplies 103/2509 by 231/2509. Moreover, because Mariamne's name appears in the Talpiot tomb with the further designation "e Mara" and because Yose admits a variant, he multiplies the relative frequencies next to Mariamne and Yose by a "combinatorial factor" of 2. This yields the following probabilities:[8]

Yeshua bar Yehosef: $103/2{,}509 \times 231/2{,}509 = p_1$
Mariamne: $2 \times 1/317 = p_2$
Marya: $26/317 = p_3$
Yose: $2 \times 9/2{,}509 = p_4$

Because how one person is named is thought not to affect how another person is named, Feuerverger treats these probabilities as independent, which means that the joint probability of these names is the product of the individual probabilities (see appendix A.6).[9] He therefore multiplies these probabilities together, yielding the probability

$$q = p_1 \times p_2 \times p_3 \times p_4,$$

which is approximately 1 in 71,000,000.

Next, Feuerverger multiplies this number by three correction factors:

- Correction for number of 4-name clusters as "surprising" as this one: $c_1 = 30$.
- Correction for names missing from Talpiot tomb expected to be there if this truly were the tomb of the New Testament Jesus: $c_2 = 4$.
- Correction for the number of tombs that might have displayed this cluster of names: $c_3 = 1{,}000$

The motivation for these correction factors is as follows:

Regarding c_1: Imagine that you are playing poker and win the game by drawing a royal flush in the suit of spades. Someone exclaims, "What an incredible hand. The odds against getting it by chance are 1 in 2,598,960. You must have been cheating!" In response, you point out that the odds really aren't quite that drastically small. Yes, getting a royal flush in the suit of spades has that precise probability, but there are also royal flushes in the suits of clubs, diamonds, and hearts. Presumably, your interlocutor, who accused you of cheating for getting a royal flush in the suit of spades, would also have accused you of cheating if you had gotten a royal flush in any of these other suits, each of these hands being as "surprising" as the one you got. But in that case, the relevant probability is not that of getting a royal flush in one particular suit but rather of getting a royal flush in any suit. Accordingly, one needs to multiply this 1-in-2,598,960 improbability by 4, which serves as a correction factor that raises this probability to 1 in 649,740.

Similarly, Feuerverger multiplies his 1 in 71,000,000 improbability (= q) by a correction factor of $c_1 = 30$ to take into account all the other 4-name clusters that match up as surprisingly with the family of the New Testament Jesus. Consider, for instance, what would have happened if the Talpiot tomb included, as before, the names Yeshua bar Yehosef, Marya, and Mariamne, but then substituted Yaakov bar Yehosef (James son of Joseph) for Yose. This new pattern of names would constitute as surprising a match-up with the family of the New Testament Jesus as the pattern of names actually discovered. Just as different ways of obtaining a royal flush need to be factored into assessing the improbability of a royal flush, so different patterns of names that are to the same degree characteristic of the family of the New Testament Jesus as the one actually discovered need to be factored into any assessment of whether the pattern of names actually discovered is unlikely to have occurred by chance. Given Feuerverger's correction factor to adjust for "surprisingness," his improbability of 1 in 71,000,000 now comes down to 1 in 2,400,000 (= $q \times c_1$), a number that appears prominently in the "Jesus Family Tomb" literature.

Regarding c_2: Imagine that you are a detective trying to uncover a husband-and-wife blackmailing team. You don't have photos of the pair, but you have detailed physical descriptions as well as extensive dossiers that describe their personal habits. In particular, you have it on good authority that they are virtually inseparable. In your investigation, you find a man who matches the physical description of the husband to a tee. But, as you track his movements, you never see him with a woman who could in any way be construed as a consort. If all you knew about the suspect was that he closely matched the physical description of the criminal in question, you would think it highly probable that you've got the right man. But when you factor in the absence of a woman, who is known to be constantly together with the criminal, you are no longer so sure that you've got the right man. Now the probability of having the wrong man goes up.

Likewise, with the Talpiot tomb, not only are certain New Testament names conspicuous by their presence, but others are conspicuous by their absence. Jesus the son of Joseph has to be there. But what about James the son of Joseph, the brother of Jesus (Mark 6:3)? In his letter to the Galatians (regarded by many scholars as the earliest writing in the New Testament—ca. 49 AD), Paul refers to James as a "pillar" of the church (Gal. 2:9). According to the book of Acts, James was an important leader in the Jerusalem church. As a prominent member of Jesus' family who was also active in Jerusalem (and thus near the Talpiot tomb), why does he not merit an ossuary displaying his name in that tomb if it is indeed the family tomb of the New Testament Jesus? In 2002, an ossuary was discovered that bears just such an inscription (i.e., "James son of Joseph, brother of Jesus"). But its provenance is uncertain and it is widely suspected to be a forgery. And although the "Jesus Family Tomb" people have suggested that the "James ossuary" originally belonged to the Talpiot tomb,[10] their chief statistician Andrey Feuerverger takes the absence of James's name (and that of others in Jesus' family, such as Joseph himself and Judah the brother of Jesus, both of whom are absent from the tomb) as reason to attenuate the probability that the Talpiot tomb belongs to Jesus' family. Feuerverger therefore multiplies the probability of 1 in 2,400,000 (= $q \times c_1$) by $c_2 = 4$, yielding a probability of 1 in 600,000 (= $q \times c_1 \times c_2$) "in favor of the tomb belonging to the family of Jesus of Nazareth."[11]

Regarding c_3: Imagine that your daughter comes up to you claiming that she just tossed ten heads in a row with a penny. That's quite a remarkable repetition of heads, you think. You examine the penny, and it appears to be a fair coin (i.e., a rigid homogeneous flat, rather than warped, disk with distinguishable sides). Moreover, when you question your daughter, she assures you that she really gave the coin a good jolt each time—these were not phony flips. Yet before you accept that this succession of heads was a remarkable coincidence (the improbability of tossing a coin ten times and getting ten heads in a row is about 1 in 1,000, and therefore is more extreme than the 1 in 600 put forward by the "Jesus Family Tomb" people), you have one more question for your daughter: how many times did she toss the coin before coming to you and reporting this remarkable succession of heads. As it turns out, she was tossing the coin all afternoon. You do a quick calculation and determine that she tossed the coin two- to three-thousand times. With that many tosses, it becomes highly likely that she would witness a run of ten heads. When she finally did, she reported it to you.

At issue in this example is what statisticians call *the file-drawer effect*. The file-drawer effect refers to events that end up in a "file-drawer" unreported before an event of interest finally is reported. The file-drawer acts as a trash can that relegates to oblivion results we would rather ignore and forget. Thus, in determining whether and to what extent an event is improbable, we need to factor in what ended up in the file-drawer. Specifically, we need to factor in how many opportunities there were for the event in question to happen (such opportunities are called *probabilistic resources*—see appendix A.9). Only then does it become clear whether an event is truly improbable. To fail to factor in what's in the file drawer is to commit *the file-drawer fallacy*. Thus, in the case of the Talpiot tomb, it is not enough merely to consider how improbable it was for the pattern of names observed there to occur by chance. That same pattern of names could also have occurred in other tombs. Feuerverger therefore introduced the correction factor $c_3 = 1{,}000$ as "the maximum number of tombs that might have once existed in Jerusalem, dating to the first century."[12] By multiplying the probability of 1 in 600,000 (= $q \times c_1 \times c_2$) by c_3, Feuerverger obtained a probability of 1 in 600 (= $q \times c_1 \times c_2 \times c_3$).

Here, then, is how the "Jesus Family Tomb" people arrived at their improbability of 1 in 600. Since $q = p_1 \times p_2 \times p_3 \times p_4$, the Jesus equation may therefore be rewritten as

$$\frac{1}{600} = p_1 \times p_2 \times p_3 \times p_4 \times c_1 \times c_2 \times c_3,$$

where p_1 = 103/2,509 x 231/2,509 (the Yeshua-bar-Yehosef probability), p_2 = 2 x 1/317 (the Mariamne probability), p_3 = 26/317 (the Marya probability), p_4 = 2 x 9/2,509 (the Yose probability), c_1 = 30 (correcting for equally surprising patterns of names), c_2 = 4 (correcting for absence of expected names), c_3 = 1,000 (correcting for the chance of seeing the same pattern of names in other tombs).

Can this equation statistically justify that the Talpiot tomb is the family tomb of the New Testament Jesus? There are too many problems with this equation for it to accomplish this task. We turn to these problems next.

5 Problems with the Jesus Equation

5.1 Incorrect Calculation of Basic Probabilities

Let E denote the event of a Jewish person around the time of Jesus being named Joseph and F the event of a Jewish person around the time of Jesus being named Mary. Based on Tal Ilan's *Lexicon of Jewish Names in Late Antiquity*, the "Jesus Family Tomb" people assigned a probability of 231/2,509 to E and a probability of 80/317 to F. But this assignment is incorrect. These probabilities are conditional on the gender of the person named (out of the 2,509 men's names in the lexicon, 231 were some variant of Joseph; out of the 317 women's names, 80 were some variant of Mary). Since E denotes the naming of a male and F the naming of a female, $\mathbf{P}(E)$ = $\mathbf{P}(E$ & Person-Named-Is-Male) = $\mathbf{P}(E$ | Person-Named-Is-Male) x $\mathbf{P}$(Person-Named-Is-Male) = 231/2,509 x 1/2 and $\mathbf{P}(F)$ = $\mathbf{P}(F$ & Person-Named-Is-Female) = $\mathbf{P}(F$ | Person-Named-Is-Female) x $\mathbf{P}$(Person-Named-Is-Female) = 80/317 x 1/2. (For the relevant math, see appendices A.4 and A.5.)

Note that the probability of 1/2 here corresponds to the roughly equal proportion of males and females (i.e., $\mathbf{P}$(Person-Named-Is-Male) = $\mathbf{P}$(Person-Named-Is-Female = 1/2). Note also that $\mathbf{P}(E$ | Person-Named-Is-Male) and not $\mathbf{P}(E)$ is the probability that is properly assigned 231/2,509 and likewise $\mathbf{P}(F$ | Person-Named-Is-Female) and not $\mathbf{P}(F)$ is the probability that is properly assigned 80/317. In consequence, to legitimately multiply the probabilities in the Jesus equation, each of them must first be multiplied by a factor of 1/2 (or else by the probability of the relevant gender if it differs from 1/2). Otherwise, multiplying these probabilities is like combining apples and oranges. This additional factor of 1/2 for each of the probabilities in the Jesus equation seems, at first blush, to intensify the statistical challenge posed by the "Jesus Family Tomb" people, rendering it even more improbable that the Talpiot tomb could by chance be other than the tomb of Jesus. Other things being equal, that would be the case. But other things are not equal, as we show next.

5.2 Fallacy of Over-Specification

In the New Testament, written in Greek, Mary the mother of Jesus as well as Mary Magdalene are always referred to with the commonest Greek forms of the name Mary: *Μαρία* and *Μαρίαμ* (i.e., Maria and Mariam).[13] To find less common variants of the name in the Talpiot tomb and then use the probabilities of these less common variants to calculate the probability of the pattern of New Testament names in the tomb is to commit a fallacy of over-specification, narrowing the range of the target in question more than is warranted. To see what's at stake in this fallacy, imagine that you reside in Chicago, a city of approximately 3,000,000. As you're riding the subway one day, you overhear two people raving about a certain Susan Smith, who they claim is the best masseuse in Chicago. Your neck is killing you, and you think, "Wouldn't it be nice if I could meet this woman some time and have her give my neck a massage." A week later, you're flying from Chicago to New York, and seated next to you is a woman. Attached to her carry-on bag is an address label. As you glance at it, you notice that it reads "Suzanne Smythe, Chicago, Illinois."

Those two chaps on the subway never spelled the name, and for all you know there could be hundreds of Susan Smiths (with the usual spelling) in the Chicago area. But "Suzanne Smythe" is an unusual spelling. You think it's unlikely that there are any other in the Chicago area. Just to make sure, you ask this person about the spelling of her name and its pronunciation. She admits that it is an unusual spelling (she's the only one in the phone book) and notes that it is pronounced just the same as "Susan Smith." At this point, do you reason that because the spelling of this name is so improbable, the person seated next to you must be the masseuse described by the two subway riders on whom you were eavesdropping? Without further information, do you ask, "Hey, how about giving me a massage?" Of course not. And yet that is essentially what the "Jesus Family Tomb" people are doing when they use the improbability of variant spellings of Mary to claim that the Talpiot tomb is the family tomb of the New Testament Jesus.

To know whether the Suzanne Smythe you met on the plane is the masseuse described on the subway, you need additional relevant information. If you learn that she is a masseuse, that will be reason (though not conclusive reason) to think that she is the same person as described on the subway. If you learn that the names of her friends correspond to those described by the chaps on the subway, that will also be reason (though not conclusive reason) to think she is the same person. Now, the "Jesus Family Tomb" people claim to have such additional information. In our analogy, overhearing the subway talkers describe Susan Smith is like reading the New Testament account of Mary Magdalene. Coming across an ossuary with the name Mariamne is like bumping into Suzanne Smythe on the airplane. But, the "Jesus Family Tomb" people would add, the analogy now becomes imperfect because there's additional evidence that Mary Magdalene was referred to as Mariamne, and this strongly suggests that the Mariamne in the Talpiot tomb is indeed Mary Magdalene.

But what is this evidence? Principally it derives from a fourth century apocryphal book known as the *Acts of Philip*, which refers to a Mariamne who is the sister of Philip. This book describes Mariamne and Philip's missionary journeys after Jesus ascends to heaven. The book gives no indication that this Mariamne is Mary Magdalene, much less that she was married to Jesus.[14] For a text suggesting that Jesus was married to Mary Magdalene, the closest one can find is the apocryphal *Gospel of Philip*, which depicts Mary Magdalene as Jesus' favorite disciple, but gives no indication that they were married. Moreover, in that text, she is referred to as Mary, not as Mariamne.[15] In any case, François Bovon, the leading authority on the *Acts of Philip*, writes,

> As I was interviewed for the Discovery Channel's program *The Lost Tomb of Jesus,* I would like to express my opinion here. . . . [H]aving watched the film, in listening to it, I hear two voices, a kind of *double discours*. On one hand there is the wish to open a scholarly discussion; on the other there is the wish to push a personal agenda. I must say that the reconstructions of Jesus' marriage with Mary Magdalene and the birth of a child belong for me to science fiction. . . . I do not believe that Mariamne is the real name of Mary of Magdalene. Mariamne is, besides Maria or Mariam, a possible Greek equivalent, attested by Josephus, Origen, and the *Acts of Philip*, for the Semitic Myriam.[16]

Return to our Susan Smith analogy: imagine while riding on the Chicago subway that you heard about a wonder-masseuse with a name that sounds like Susan Smith (this corresponds, in the analogy, to reading about Mary Magadalene in the New Testament) and then sat next to Suzanne Smythe on an airplane, learning only the spelling of name (this corresponds to finding the ossuary inscribed Mariamne in the Talpiot tomb). On reading a vast literature in which a wonder-masseuse from Chicago is consistently referred to as "Susan Smith" (this corresponds to reading the vast literature of Church Fathers and New Testament apocrypha that consistently refers to Mary Magdalene as "Mary"), you find that a few passages in this vast literature refer to a "Suzanne Smythe," though it's not at all clear from these passages that this is the Chicago masseuse (this corresponds to the reference to Mariamne in the *Acts of Philip*). In that case, there's no more reason to think that the Suzanne Smythe you met on the airplane is the wonder-masseuse from Chicago than to think that the bones of the Mariamne found in the Talpiot tomb are those of Mary Magdalene. Here, "Suzanne Smythe" is no more characteristic of Chicago's wonder-masseuse than "Susan Smith"; likewise, "Mariamne" is no more characteristic of the New Testament woman from Magdala than plain-old "Mary."

It follows that in assessing the probability that chance could produce the pattern of New Testament names found in the Talpiot tomb, the relevant probability for Mariamne is not the low probability of that particular name but the high probability of the generic form of Mary. Exactly the same reasoning applies to the other Mary in that tomb, referred to by the "Jesus Family Tomb" people as Marya and thought by them to be the mother of Jesus. The probability associated with her name needs likewise to be the high probability of the generic form of Mary.

That leaves the names Yeshua bar Yehosef and Yose. The probability that the "Jesus Family Tomb" people associate with Yeshua bar Yehosef seems right, save for the factor of 1/2 by which the name needs to be made conditional on this person being male (see the previous subsection). As for the probability they associate with Yose, it, as with the two Marys, is too small. A case can be made that the "Jesus Family Tomb" people were guilty of a fallacy of over-specification here as well since Yose is just a short form of Joseph, and even though a brother of Jesus is referred to as Yose in Mark 6:3, that same brother is referred to by the unshortened form of Joseph in Matthew 13:55. But since Yose is distinguished from another Joseph in the Talpiot tomb (namely, the father of Jesus), a case can also be made that the pattern of New Testament names in the Talpiot specifies Yose and not merely the generic Joseph. If we do that, we get a probability for Yose that is less than that for a generic Joseph. Even so, we don't get a probability as small as the one calculated by the "Jesus Family Tomb" people. The problem is that there were several written variants of Yose that sound alike (compare Cathy with Kathy and Kathie). In a largely oral culture in which spelling was often up for grabs (there were no dictionaries or spell checkers), these alternate spelling must be factored into any specification of Yose. Richard Bauckham counts 34 such instances in Tal Ilan's lexicon, up from the 9 used by the "Jesus Family Tomb" people.[17]

Given the considerations adduced in this and the last subsection, we submit that the basic probabilities associated with the New Testament names found in the Talpiot tomb need to be recalculated as follows (note the factors of 1/2 per subsection 5.1):

$p_1 = 1/2 \times 103/2{,}509 \times 231/2{,}509 \approx .00189$ (Yeshua bar Yehosef)
$p_2 = 1/2 \times 80/317 \approx .126$ (Mariamne and Marya both treated as Mary)
$p_3 = 1/2 \times 34/2{,}509 \approx .00678$ (Yose)

5.3 Unjustified Correction Factors

Correction factor c_1 (= 30; see section 4) takes into account patterns of New Testament names as surprising as the one discovered at the Talpiot tomb that would likewise have implicated the family of the New Testament Jesus. Conversely, correction factor c_2 (= 4; see section 4) takes into account the absence of certain New Testament names from the Talpiot tomb that would have been expected to be there if this really were the family tomb of the New Testament Jesus. Both these factors, considered on general statistical grounds, seem relevant to assessing the probability that the Talpiot tomb could by chance have matched up to the degree that it did with names in Jesus' family. Note, however, that the principles of statistical rationality underlying these correction factors are quite different and would need to be mixed carefully. With the correction factor c_1, the mode of probabilistic reasoning is Fisherian (i.e., finding a suitable rejection region for testing the statistical significance of a hypothesis—see appendix A.8). With the correction factor c_2, the mode of probabilistic reasoning is Bayesian (i.e., updating one's probability in light of supporting or countervailing evidence—see appendix A.10). The "Jesus Family Tomb" people never make clear how these approaches can be mixed, nor do they offer any argument or justification for how the actual numbers they assigned to these correction factors were calculated. Perhaps Andrey Feuerverger will produce such a justification in the paper he is preparing for peer-review. But for now the actual numbers assigned to these correction factors appear taken out of a hat.

5.4 Wrong Reference Population

Unlike correction factors c_1 and c_2, the "Jesus Family Tomb" people do offer a justification for how they arrived at the number they assigned to the correction factor c_3. This number, set at 1,000, estimates "the maximum number of tombs that might have once existed in Jerusalem, dating to the first century."[18] This correction factor, as we pointed out in section 4, attempts to circumvent a file-drawer fallacy in which one calculates the probability that the pattern of New Testament names discovered in the Talpiot tomb could by chance have occurred *just there*. The problem with tying such a probability calculation to a single tomb is that it fails to take into account the opportunities for this same pattern of names to occur in other tombs from that time and in that locale. Any of these other tombs might also have been a "Jesus Family Tomb." Given enough tombs, it becomes extremely likely that not just one but numerous tombs would display this pattern of New Testament names. By disregarding these other tombs and thus placing them, as it were, in a file-drawer, one fails to assess the true probability of witnessing this patterns of names by chance. Accordingly, the probability we assign to the Talpiot tomb belonging to the New Testament Jesus must factor in these additional tombs.

We have just summarized Andrey Feuerverger's justification for setting c_3 equal to 1,000. In thereby attempting to circumvent a file-drawer fallacy, he rightly underscored an important statistical principle, namely, the need to factor in the opportunities for an event to occur (known formally as its *probabilistic resources*—see appendix A.8) in assessing whether the event may rightly be regarded as improbable. Unfortunately, though aware of the principle's importance, Feuerverger also misapplied it, focusing too narrowly to the actual number of tombs near Jerusalem. There are two problems with this:

> (1) In determining whether some family or other around Jerusalem might by chance exhibit some pattern of names, what's crucial is how many such families there were and not how many of them could additionally have afforded a tomb with ossuaries. The correction factor c_3 therefore should not have been set to the maximum number of actual tombs in the Jerusalem area around the time of Jesus but to the total number of relevant families in the area—regardless of whether they had the financial resources to own a tomb. Most families in the time of Jesus were too poor to afford such tombs. In particular, because Joseph, Jesus' legal father, was a carpenter and because carpentry was not a lucrative profession, Jesus' family seems not to have been an ideal candidate for having a family tomb. Accordingly, what's crucial in assessing the probability that the Talpiot tomb was the family tomb of Jesus is not the actual number of family tombs but the actual number of families living at that time and in that area.

(2) The second problem is that Feuerverger focuses unduly on Jerusalem and its immediate surroundings. Yes, the Talpiot tomb is just a few miles from Jerusalem and, yes, Jesus' brother James was active in Jerusalem. If we knew nothing else, we might therefore think it likely that James should be buried in the immediate vicinity of Jerusalem (though the evidence is against his having an ossuary in the Talpiot tomb). But we know a lot more. We know that Jesus and his family throughout his life was based 65 miles north of Jerusalem in the town of Nazareth—in fact he is often called "Jesus of Nazareth." Moreover, Magdala, the town from which Mary Magdalene hails, is fifteen miles still further north. Thus the number of families in the immediate vicinity of Jerusalem in the period of ossuary use underestimates the number of relevant families to deciding whether the Talpiot tomb is, on probabilistic grounds, the tomb of Jesus.[19] In calculating this number of families, we need to consider a radius of at least 80 miles around Jerusalem. In other words, we need to consider all Jewish families living in ancient Palestine during the time that ossuaries were popular.

How many such families lived in Palestine during that time? To answer this question, let's start with a simpler question: How many Jewish people as such lived in Palestine during the period of ossuary use? A conservative lower-bound estimate is 500,000 on the number of Jewish people living in Palestine at any one point in time during that period.[20] Moreover, the period of ossuary use spans 100-years.[21] Given that the average lifespan during that period was well under 50 years, a conservative lower-bound estimate on the number of Jewish people living in Palestine during that entire period is twice 500,000, or 1,000,000. Given an average of 10 people per family, as in the Talpiot tomb, that would leave 100,000 families as the right reference population for any probability calculations used to infer that the Talpiot tomb is the final resting place of Jesus.

6 The New and Improved Jesus Equation

In the previous section we analyzed the problems with Andrey Feuerverger's Jesus equation. This analysis now suggests a new and improved Jesus equation. Given an arbitrary family of size n and given k distinct names, if in the wider population the first name has probability p_1, the second p_2, and so on through k, then the probability p that this family will by chance have at least m_1 family members with the first name, at least m_2 with the second, and so on through k, where each m_i ($1 \leq i \leq k$) is at least 1, is governed by the multinomial distribution and has the following value:[22]

$$p = \sum_{\substack{n_1+n_2+\cdots+n_k+n_{k+1}=n \\ n_1 \geqslant m_1,\ldots,n_k \geqslant m_k, n_{k+1} \geqslant 0}} \frac{n!}{n_1!n_2!\cdots n_k!n_{k+1}!} p_1^{n_1} p_2^{n_2} \cdots p_k^{n_k} p_{k+1}^{n_{k+1}}$$

This, then, is the new and improved Jesus equation. Even though it looks complicated, summing over these multinomial terms on the right to evaluate p is standard fare in introductory probability and statistics courses. The calculation is tedious but conceptually straightforward. Note that p_{k+1} is the probability that none of the k names in question are selected at random; hence $p_{k+1} = 1 - (p_1 + p_2 + \cdots + p_k)$. Note also that all the probabilities p_i $(1 \le i \le k+1)$ are strictly positive (i.e., none of them is a zero probability). Note lastly that factorials in this equation (e.g., $n! = 1 \times 2 \times \cdots \times n$) take into account combinatorial possibilities that were mistakenly ignored the original Jesus equation. These combinatorial terms make the probability that the Talpiot tomb by chance acquired its pattern of New Testament names much larger than the 1 in 600 value computed by the "Jesus Family Tomb" people.

Two additional numbers, derived from p, are going to be crucial in assessing whether probabilities support the hypothesis that the Talpiot tomb is the final resting place of Jesus. To calculate these numbers, we first need an estimate for the number of Jewish people living in ancient Palestine while ossuaries were in use. Let us call this number N. As we saw in subsection 5.4, a conservative estimate for this number is 1,000,000. By contrast, the "Jesus Family Tomb" people were in fact willing to countenance 5,000,000 as an estimate for N.[23] In the sequel we therefore take N to be 1,000,000. With N in hand, the fraction N/n estimates the number of families of size n during that time. Granted, this estimate is somewhat rough in that it treats families as having the same size and as constituting non-overlapping units, which strictly speaking they do not. But, this assumption seems unproblematic since variability of family size and overlap among families will tend to push up the number of families and therefore the opportunities for families to exhibit the pattern of New Testament names found in the Talpiot tomb. In any case, given N and N/n, we now define the following two numbers:

$$p^* = 1 - (1 - p)^{N/n},$$

$$M = (N/n) \times p.$$

p^* is the probability that at least one out of N/n families exhibits the pattern of names in question if the probability that a single family exhibits that pattern of names is p. The underlying assumption here is that naming across different families is probabilistically independent (i.e., how one family names its children does not affect the probabilities of how other families name their children). Accordingly, the probability that no family of size n has this pattern of names is $(1 - p)^{N/n}$ (here $1 - p$ is the probability that a particular family of size n does not have that pattern of names, which then, by the independence assumption, gets multiplied by itself N/n times). It follows in turn that the complementary event (i.e., that at least one family of size n has this pattern of names) is therefore $1 - (1 - p)^{N/n}$.[24] Note that the independence assumption seems approximately true, especially since most families have contact with only a few other families and thus cannot name their children by consciously copying how most other families, with which they are not in contact, name their children. Note that p^* corresponds to the p-value calculated by the

“Jesus Family Tomb” people’s Jesus equation, gauging the likelihood that the Talpiot tomb is the last resting place of the New Testament Jesus.

As for M, it gives the expected number of Jesus families (i.e., families with the pattern of New Testament names observed in the Talpiot tomb) living in Palestine during the period of ossuary use. To see that $M = (N/n) \times p$ does indeed give the expected number of Jesus families, treat each Jewish family living in Palestine during that period as a Bernoulli trial (i.e., as a binary, success-failure trial) with probability p of successfully obtaining the pattern of names observed in the Talpiot tomb. Then the number of families exhibiting this pattern follows a binomial distribution with probability p of success on any individual trial and with total number of trials N/n.[25] The “Jesus Family Tomb” people suggest that any reasonable way of calculating the expected number of Jesus families will never yield a number greater than 1. But they are mistaken, as we see next by calculating p, p^*, and M for four instructive cases:

Case 1:

$n = 10$; $N = 1{,}000{,}000$; $m_1 = m_2 = m_3 = m_4 = 1$
$p_1 = 1/2 \times 103/2{,}509 \times 231/2{,}509$ (Yeshua bar Yehosef)
$p_2 = 1/2 \times 2 \times 1/317$ (Mariamne)
$p_3 = 1/2 \times 26/317$ (Marya)
$p_4 = 1/2 \times 2 \times 9/2{,}509$ (Yose)

$p = 1.9154 \times 10^{-6}$; $p^* = .1743$; $M = .1915$

Case 2:

$n = 20$; $N = 1{,}000{,}000$; $m_1 = m_2 = m_3 = m_4 = 1$
$p_1 = 1/2 \times 103/2{,}509 \times 231/2{,}509$ (Yeshua bar Yehosef)
$p_2 = 1/2 \times 2 \times 1/317$ (Mariamne)
$p_3 = 1/2 \times 26/317$ (Marya)
$p_4 = 1/2 \times 2 \times 9/2{,}509$ (Yose)

$p = 3.5229 \times 10^{-5}$; $p^* = .8282$; $M = 1.7615$

Case 3:

$n = 10$; $N = 1{,}000{,}000$; $m_1 = m_3 = 1$; $m_2 = 2$
$p_1 = 1/2 \times 103/2{,}509 \times 231/2{,}509 \approx .00189$ (Yeshua bar Yehosef)
$p_2 = 1/2 \times 80/317 \approx .126$ (Mariamne and Marya both treated as Mary)
$p_3 = 1/2 \times 34/2{,}509 \approx .00678$ (Yose)

$p = 2.9960 \times 10^{-4}$; $p^* = 1 - 9.6959 \times 10^{-14} \approx 1$; $M = 30$

Case 4:

$n = 20$; $N = 1{,}000{,}000$; $m_1 = m_3 = 1$; $m_2 = 2$
$p_1 = 1/2 \times 103/2{,}509 \times 231/2{,}509 \approx .00189$ (Yeshua bar Yehosef)
$p_2 = 1/2 \times 80/317 \approx .126$ (Mariamne and Marya both treated as Mary)
$p_3 = 1/2 \times 34/2{,}509 \approx .00678$ (Yose)

$p = 3.0838 \times 10^{-3}$; $p^* = 1 - 8.5639 \times 10^{-68} \approx 1$; $M = 154$

In cases 1 and 3, we equate family size *n* with 10. This seems a low-end estimate of family size. From the New Testament, we know that Jesus had Joseph and Mary as legal parents, four brothers, and at least two sisters (see Mark 6). That makes at least 9 family members right there in but two generations, excluding spouses. In the Talpiot tomb, which may span three or more generations, we find 10 ossuaries, and some of them may contain the bones of more than one person. Indeed, given the size of families back then and naturalness of including three generations (grandparents, parents, and children) in a family unit, equating family size *n* with 20 seems more in keeping with the average size of families back then. Hence, the value of *n* in cases 2 and 4.

N, the number of Jews living in Palestine during the period of ossuary use, is set conservatively at 1,000,000, and is constant in all four cases. As we noted in subsection 5.4, this reference class for the tomb probabilities is more appropriate than estimates for the population size of Jerusalem since Jesus and his family were based 65 miles north of Jerusalem in Nazareth and around the sea of Galilee. In cases 1 and 2, we go with the probability of individual names as assigned by the "Jesus Family Tomb" people (see the probabilities section 4, though these have to be multiplied additionally by a factor 1/2 to take into account gender differences—see subsection 5.1). This takes the probabilities of Mariamne, Marya, and Yose way down. In cases 3 and 4, by contrast, we go with the more realistic estimates of probabilities for these names as given and justified in subsection 5.2 (this collapses Mariamne and Marya into a generic Mary).

In cases and 1 and 2, p^* is the number of interest and corresponds to the probability of at least one Jewish family in Palestine while ossuaries were in use having the pattern of New Testament names observed in the Talpiot tomb. As such, it corresponds to the *p*-value calculated by Andrey Feuerverger and used to assess the probability that this could be Jesus family tomb. But even though we use the same probabilities for individual Jewish names as used by the "Jesus Family Tomb" people, we don't get anywhere near as "impressive" results as they did. In place of 1 in 600 for this pattern of names occurring by chance as in the original Jesus equation, with the new and improved Jesus equation, we find that for family size $n = 10$ the probability rises to better than 1 in 6 (.1743) and for $n = 20$ the probability rises even more dramatically to better than 4 in 5 (.8282).[26] No statistical theory regards these numbers as remarkable or even statistically significant.

In cases 3 and 4, *M* is the number of interest and corresponds to the number of Jewish families of a given size *n* we could expect to see exhibit the pattern of New Testament names found in the Talpiot tomb. Given realistic naming probabilities, we find that for small families of size 10 we would expect to see 30 of them exhibit the Talpiot pattern of New Testament of names and for medium families of size 20 we would expect to see 154 of them exhibit this pattern of names. Even in case 2, taking family size at 20, we are more likely to see 2 rather than 1 family with the more restrictive name set and lowered probabilities promoted by the “Jesus Family Tomb” people.

Bottom line: when the math is done correctly, probabilities that might be cited in evidence for the Talpiot tomb being the final resting place of the New Testament Jesus are not very impressive and would not even achieve a minimal level of significance as gauged by conventional statistical theory.

7 Eliminating Reasonable Doubt

To an outsider coming to this debate over probabilities connected with the pattern of New Testament names found in the Talpiot tomb, it may seem that the “Jesus Family Tomb” people still have a point. Granted, the probabilities are not nearly as bad as they make out (see the previous section). But by going with their numbers, it would seem that at most one or two Jewish families around the time of Jesus might have exhibited this pattern of names. And by going with our numbers, it would seem that at least thirty Jewish families around the time of Jesus would have exhibited this pattern of names. An outsider with no stake in this debate might therefore conclude that a handful (say five or so) Jewish families around the time of Jesus are likely to have exhibited this pattern of names. But in that case, it would seem that the Talpiot tomb might still have a good shot at being the family tomb of the New Testament Jesus. To be sure, the probabilities would suggest that this is not Jesus’ tomb. But, at the same time, they would leave a reasonable doubt that it is.

We want in this section to close off this loophole. To do so, we employ a consequence of Bayes’s theorem (see appendices A.9 and A.10). Bayes’s theorem may be thought of as a way to update probabilities in light of additional information or evidence. The probabilities we assign are always subject to change in light of additional information or evidence. To illustrate this fact about probabilities, take the case of someone we’ll call George. For the last five years George has religiously worked out at the health club Mondays, Wednesdays, and Fridays at 7:00pm. He hasn’t missed a workout for five years. Today is Monday. What is the probability that George will work out today at 7:00pm? Given the information just presented, you would rightly assign a high probability to this event. But suppose next you learn that George has just been in a terrible car accident and is on life support. What is the probability that George will be working out tonight? Given this additional information, the probability goes way down. But suppose next you learn that George’s buddies can’t stand to see their friend miss a workout and so are planning to sneak into the hospital and remove George, taking him to the health club and putting him on the workout machines, forcing his shattered body to go through exercise motions. Now the probability goes up. By adding still further information, the probability can continue to go down and up.

To see how this updating of probability works in the case of the Talpiot tomb, let **J** denote the hypothesis that this tomb is the final resting place of the New Testament Jesus and let **~J** denote the negation of this hypothesis (see appendix A.4). Then, if the expected number of Jesus families, denoted by M, is at least two, one can rationalize assigning a probability of $1/M$ to **J** and $(M-1)/M$ to **~J**, in other words, **P**(**J**) = $1/M$ and **P**(**~J**) = $(M-1)/M$. Moreover, if M is not even 1, one can rationalize assigning a probability of p^* to **~J** and $1-p^*$ to **J**, in other words, **P**(**J**) = $1-p^*$ and **P**(**~J**) = p^*. Given that p^* corresponds to the p-value calculated by the "Jesus Family Tomb" people, this is in fact how the "Jesus Family Tomb" people interpret **P**(**J**) and **P**(**~J**).[27]

Suppose now we go with the worst-case probabilistic scenario from the vantage of those who think, as we do, that **~J** rather than **J** is true—in other words, we go with case 1 in section 6. Here **P**(**~J**) = .1743, or approximately 1 in 6, thus making **P**(**J**) approximately 5 in 6. If you were a betting man, it would seem that you should therefore bet that the Talpiot tomb is in fact the final resting place of Jesus even if it doesn't quite make the grade that statisticians would regard as significant. And even if these numbers were reversed (i.e., **P**(**J**) equals 1 in 6 and **P**(**~J**) equals 5 in 6), one would still, if one had no other information, be in one's rights to suspect that the Talpiot tomb might indeed be the final resting place of Jesus. But there is other information, and its inclusion radically revises the probabilities **P**(**J**) and **P**(**~J**), even in the worst-case scenario where **P**(**~J**) = .1743.

The point is that we know a lot about Jesus that undercuts the probability of his being buried in the Talpiot tomb. Consider the following items of information:

- The New Testament evidence that Jesus and his family was of modest means and therefore would be unlikely to be able to afford a tomb.

- The fact that Jesus and his family hailed from Nazareth, which was sixty-five miles north of Jerusalem, and that his supposed wife, as conjectured by the "Jesus Family Tomb" people (i.e., Mary Magdalene), was from the town of Magdala even further north of Jerusalem.

- The uniform witness of the best attested historical sources that Jesus was unmarried, to say nothing of his not being married to Mary Magdalene.

- The widespread perception shortly after Jesus' crucifixion that he had been resurrected (Paul, writing in Galatians, which both liberal and conservative scholars date around 50 AD, demonstrates a clearly developed understanding of Jesus' resurrection). Regardless of whether Jesus actually did resurrect, the perception early on among his followers that he did and the interest of his followers in denying that

> there was any tomb that housed his bones would have tended to preclude any tomb that purported to hold his remains.

Let us now denote the conjunction of these items of information by E. In consequence of Bayes's theorem, we can now update the probabilities $\mathbf{P}(\mathbf{J})$ and $\mathbf{P}(\sim\mathbf{J})$ as follows. Because we have this additional information E in hand, we would like to form $\mathbf{P}(\mathbf{J} \mid E)$ and $\mathbf{P}(\sim\mathbf{J} \mid E)$, but to do so, we must go through Bayes's theorem. As long as $\mathbf{P}(\mathbf{J})$ and $\mathbf{P}(\sim\mathbf{J})$ fail to take into account E, $\mathbf{P}(\mathbf{J})$ is about 5 times as large as $\mathbf{P}(\sim\mathbf{J})$. To compare these two quantities, Bayesian probabilists often form their ratio: $\mathbf{P}(\sim\mathbf{J})/\mathbf{P}(\mathbf{J})$. Because this fraction is about 1/5, the preponderance of probability here favors **J**. Yet by Bayes's theorem, this ratio, when updated by E to form $\mathbf{P}(\sim\mathbf{J} \mid E)/\mathbf{P}(\mathbf{J} \mid E)$, results from multiplying $\mathbf{P}(\sim\mathbf{J})/\mathbf{P}(\mathbf{J})$ by the factor $\mathbf{P}(E \mid \sim\mathbf{J})/ \mathbf{P}(E \mid \mathbf{J})$ (see appendix A.10). In other words,

$$\frac{\mathbf{P}(\sim \mathbf{J} \mid E)}{\mathbf{P}(\mathbf{J} \mid E)} = \frac{\mathbf{P}(E \mid \sim \mathbf{J})}{\mathbf{P}(E \mid \mathbf{J})} \times \frac{\mathbf{P}(\sim \mathbf{J})}{\mathbf{P}(\mathbf{J})}$$

Even though $\mathbf{P}(\sim\mathbf{J})/\mathbf{P}(\mathbf{J})$ is about 1/5, there's every reason to think that $\mathbf{P}(E \mid \sim\mathbf{J})/ \mathbf{P}(E \mid \mathbf{J})$ is huge and will swamp the previous factor, thereby rendering $\mathbf{P}(\sim\mathbf{J} \mid E)/\mathbf{P}(\mathbf{J} \mid E)$ huge. To see this consider that the items of information in E are well attested and, on the hypothesis that that the Talpiot tomb is not the final resting place of Jesus, have probability close to 1. This is because the probability of E is unaffected if the Talpiot tomb is just another tomb unrelated to Jesus' family. On the other hand, if the Talpiot tomb is indeed the final resting place of Jesus, E becomes highly unlikely, taking $\mathbf{P}(E \mid \mathbf{J})$ close to zero. Indeed, E is deeply inconsistent with **J**. Accordingly, the ratio $\mathbf{P}(E \mid \sim\mathbf{J})/ \mathbf{P}(E \mid \mathbf{J})$ skyrockets, and the same happens to $\mathbf{P}(\sim\mathbf{J} \mid E)/\mathbf{P}(\mathbf{J} \mid E)$, urging that **~J** is far better attested than **J**. Thus, even though **J**, simply in light of the pattern of New Testament names found in the Talpiot tomb may be the preferred hypothesis, once E is factored in, **~J** becomes strongly preferred. Note that we've taken the worst-case scenario. More realistic numbers suggest that **~J** is to be preferred over **J** simply in light of the Talpiot, leaving aside independent evidence (i.e., E) against this being the tomb of the New Testament Jesus, which then, as in the worst-case scenario, eliminates reasonable doubt about this still possibly being Jesus' final resting place.

If the preceding discussion seems handwaving, welcome to the world of Bayesian probability. Often Bayesian arguments are more qualitative than strictly quantitative, suggesting ways that probabilities may radically change in light of novel information and evidence rather than providing precise calculations with well-defined numbers. It will therefore help to have an instance in mind where the calculations are precise and the numbers well-defined. Suppose you are confronted with a white ball that you've just chosen at random from one of two urns. The urn on the left contains a million black balls and one white ball whereas the urn on the right contains a million white balls and one black ball. In determining from which urn you drew your ball, someone besides yourself rolled a die and gave you the left urn if it came up 1 through 5 and the right urn if it came up 6. As with **J** and **~J** in the worst case scenario (case 1 of section 6), it is more likely, with odds of 5 to 1, that the die roll came up between 1 and 5 rather than that it came up

6. Without additional information you would therefore think that the die roll came up other than 6. But because a white ball was selected, and white balls are so much more likely to be chosen at random from the right urn than from the left urn, in fact it is far more likely that the die roll came up 6 than that it came up between 1 and 5.

This line of reasoning can be made precise. Indeed, the probabilities in this example can be calculated exactly. Let L and R denote respectively whether the left urn or the right urn was sampled (which depends respectively on whether a die roll came up between 1 and 5 or came up 6). Let B and W denote respectively whether in the process of sampling a black or white ball was selected. Then

$$\mathbf{P}(L) = 5/6$$
$$\mathbf{P}(R) = 1/6$$
$$\mathbf{P}(L \mid \mathrm{W}) = 1/200{,}001$$
$$\mathbf{P}(R \mid \mathrm{W}) = 200{,}000/200{,}001.$$

The last two probabilities here follow from Bayes's theorem (see appendix A.9). Thus, even though L (like **J**) is improbable in the absence of additional information, R (like **~J**) becomes overwhelmingly probable given that additional information. That additional information removes all reasonable doubt that the Talpiot tomb might, after all, be the family tomb of the New Testament Jesus. The statistical evidence rules decisively against this hypothesis.

8 Conclusion

The mathematics needed to determine the probability that the Talpiot tomb could by chance have exhibited the pattern of New Testament names found inscribed on its ossuaries was entirely elementary, something a bright undergraduate with a semester of probability theory could in principle have figured out. Yet University of Toronto mathematician Andrey Feuerverger, acting as the statistical expert for the "Jesus Family Tomb" people, failed to figure it out. His math was not only wrong but also inadequately developed, leaving crucial elements unjustified (e.g., his first two correction factors). In consequence, the use that the "Jesus Family Tomb" people made of his work was irresponsible. They confidently proclaimed that the Talpiot tomb was the final resting place of the New Testament Jesus when a correct, detailed, properly vetted treatment of the underlying mathematics remained to be done. We believe we have provided such a treatment in this paper. Despite bending over backwards to concede to the "Jesus Family Tomb" people all the small probabilities they ever wanted, our numbers still indicate that nothing statistically significant is going on inside the Talpiot tomb and that, in fact, the relevant statistics strongly suggest that this is *not* Jesus' final resting place. But don't take our word for it. Run the numbers yourself by visiting our website at www.jesustombmath.org.

APPENDIX: A Primer on Probability

A.1 Distinction between Outcomes and Events

Probabilities are numbers between 0 and 1 that are assigned to *events* (and by extension to objects, patterns, information, and even hypotheses). Events always occur with respect to a reference class of possibilities. Consider a die with faces 1 through 6. The reference class of possibilities in this case can be represented by the set {1, 2, 3, 4, 5, 6}. Any subset of this reference class then represents an event. For instance, the event E_{odd}, namely, "an odd number was tossed," corresponds to {1, 3, 5}. Such an event is said occur if any one of its outcomes occurs—in other words, if either a 1 is tossed or a 3 or a 5. An *outcome* is any particular thing that could happen. Outcomes can therefore be represented as singleton sets, which are sets with only one element. Thus, the outcomes associated with $E_{odd} = \{1, 3, 5\}$ are $E_1 = \{1\}$, $E_3 = \{3\}$, and $E_5 = \{5\}$. Outcomes are sometimes also called *elementary events*. Events include not only outcomes but also *composite events* such as E_{odd}, which includes more than one outcome.

A.2 The Axioms of Probability

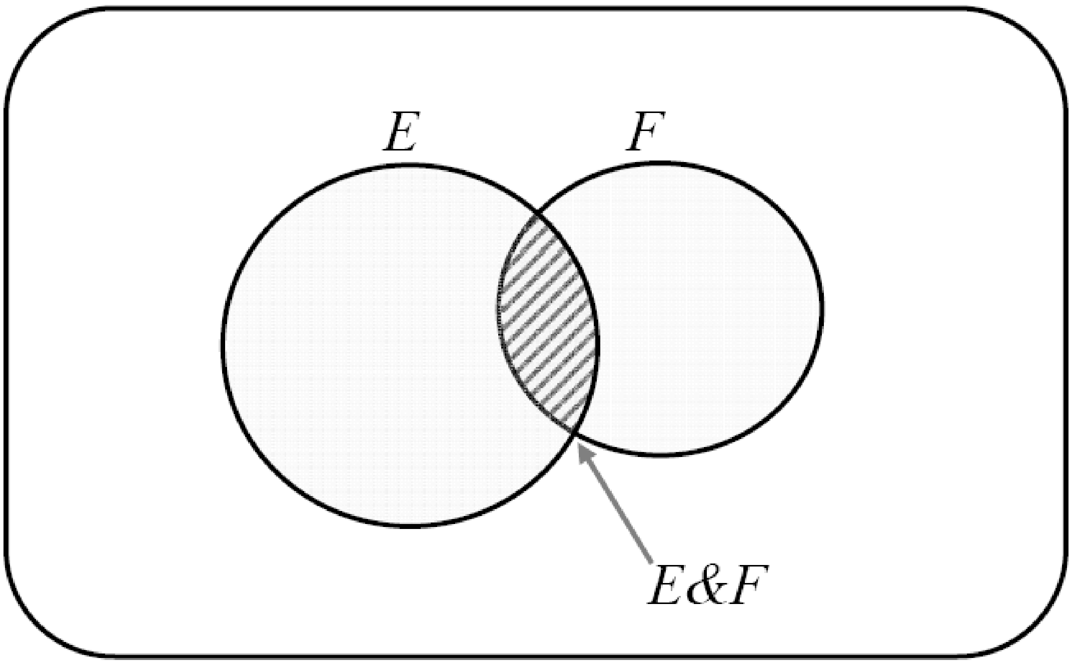
Probabilities obey the following axioms: (1) The impossible event (i.e., an event that entails a physical or logical impossibility) is represented by the empty set and has probability zero. (2) The necessary event (i.e., an event that is guaranteed to happen) is represented by the entire reference class of possibilities and has probability one (e.g., with the die example, $E_{nec} = \{1, 2, 3, 4, 5, 6\}$ has probability one). Events that are mutually exclusive have probabilities that sum together. Thus, in the previous example, $\mathbf{P}(E_{odd}) = \mathbf{P}(E_1) + \mathbf{P}(E_3) + \mathbf{P}(E_5)$ (i.e., $\mathbf{P}(\{1, 3, 5\}) = \mathbf{P}(\{1\}) + \mathbf{P}(\{3\}) + \mathbf{P}(\{5\})$). Important: mutually exclusive and exhaustive events always sum to one.

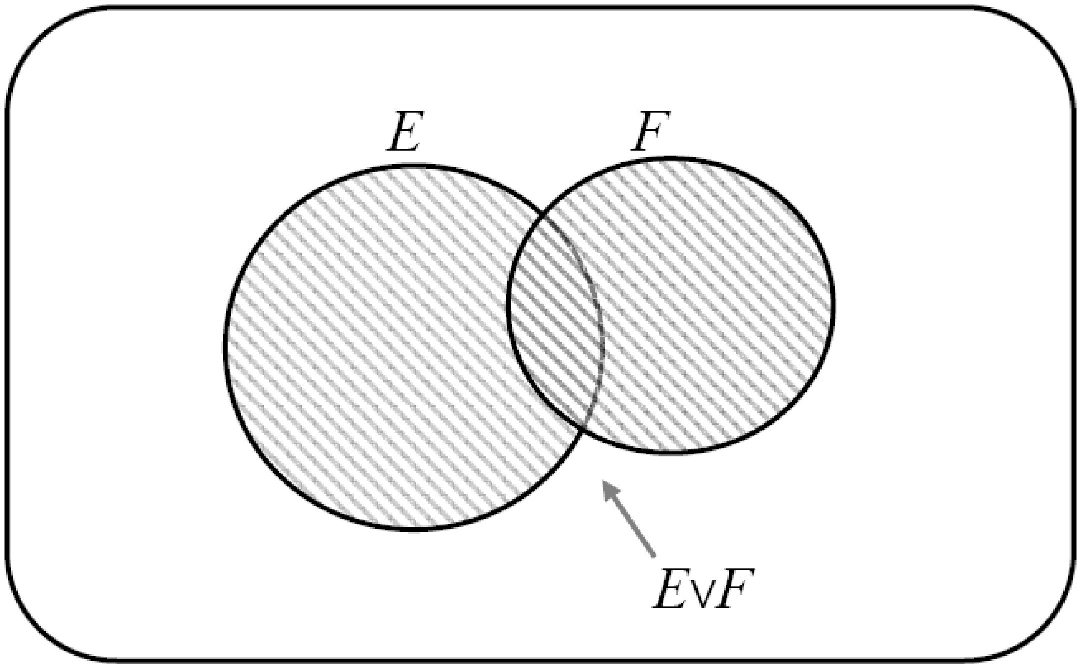
A.3 Interpretation of Probability

Probabilities are interpreted in three principal ways: (1) Frequentist approach—probability is a relative frequency (i.e., the number of occurrences of an event divided by the number of observed opportunities for the event to occur; relative frequencies are also called empirical probabilities). (2) Theoretical approach—probability derives from properties of the system generating the events (e.g., dies are rigid, homogeneous cubes whose symmetry confers probability 1/6 on each face; quantum mechanical systems have probabilities derived from eigenvalues associated with the eigenstates of an observable). (3) Degree of belief—probability measures strength of belief that an event will occur. The "Jesus Family Tomb" people focus mainly on the first of these interpretations.

A.4 Conjunction, Disjunction, and Negation

Events can form new events via conjunction, disjunction, and negation. E & F is the conjunction (or intersection, also written $E \cap F$) of E and F and denotes the event such that both E and F occur. $E \vee F$ is the disjunction (or union, also written $E \cup F$) of E and F and denotes the event such that either E or F or both occur. $\sim E$ is the negation (or complement, also written E^c) of E and denotes the event that excludes E's occurrence. In pictures:




E
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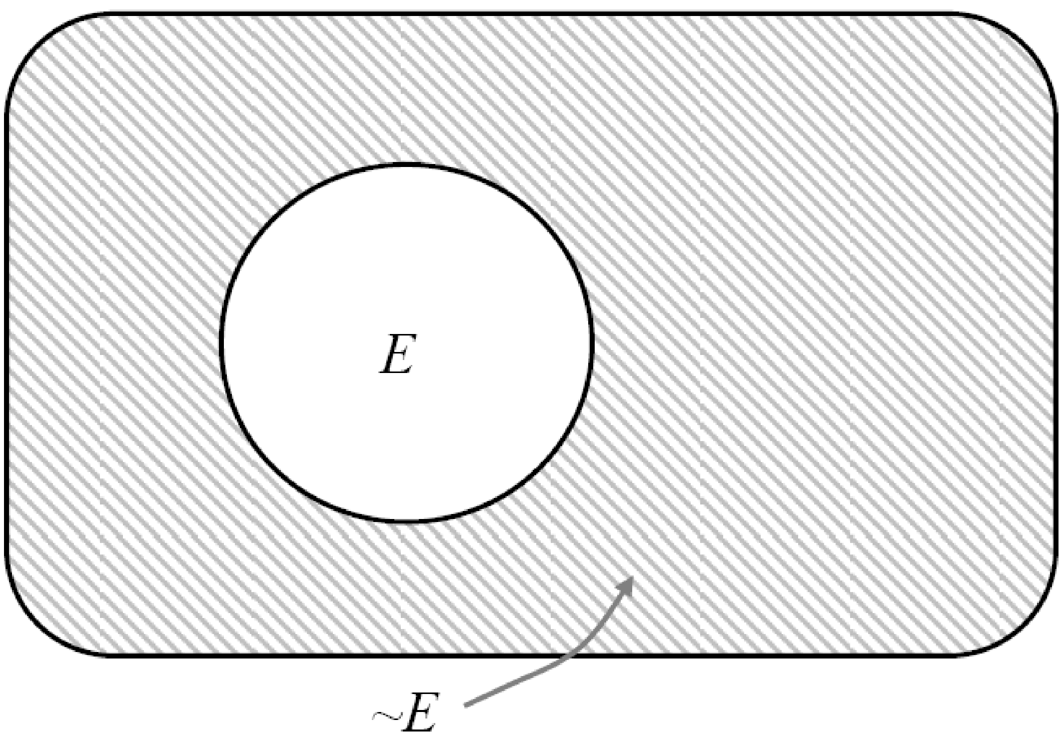
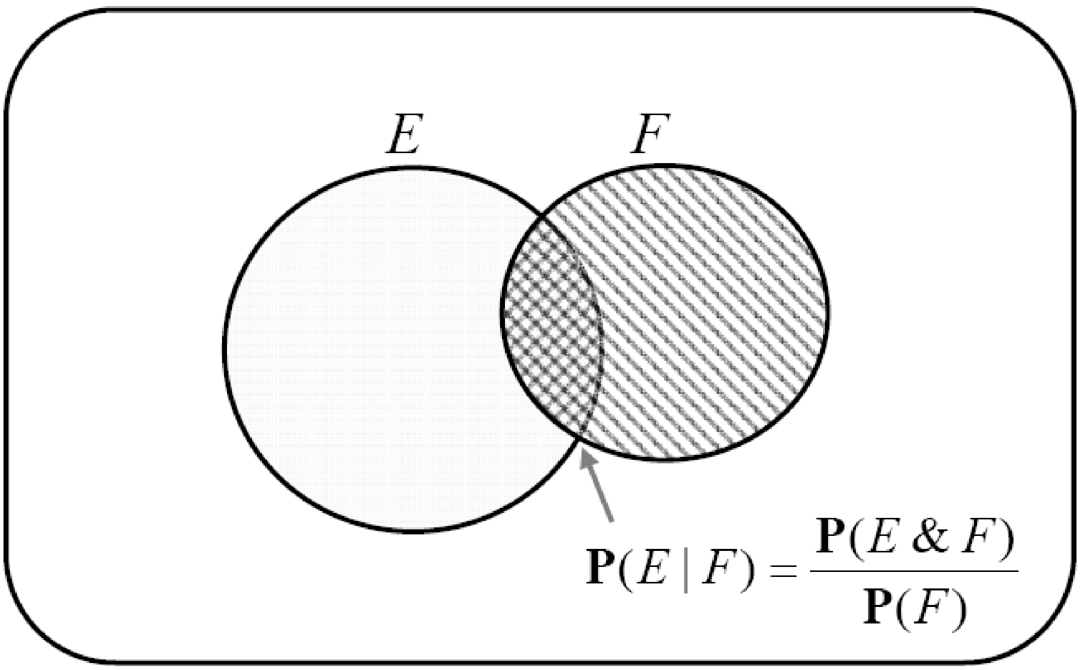

E
~E

A.5 Conditional Probability

Suppose event F is known to have occurred and we then ask what is the probability of E. In that case, the reference class of possibilities contracts to F, and the probability of E is no longer simply $\mathbf{P}(E)$ (i.e., the probability of E within the original reference class), but the probability of that portion of E that resides within the new reference class F. This probability is called the conditional probability of E given F and is written $\mathbf{P}(E|F)$. This probability is defined as

$$\mathbf{P}(E \mid F) = \frac{\mathbf{P}(E \,\&\, F)}{\mathbf{P}(F)}$$

Graphically, this probability can be represented as follows:



In assessing whether the Talpiot tomb is the tomb of the New Testament Jesus, it is critical to determine how many Jewish families in ancient Palestine might have exhibited the pattern of names associated with Jesus' family as found in that tomb. Those families constitute the reference class (i.e., F) in light of which the discovery of the pattern of names in the Talpiot tomb (i.e., E) need to be assessed. That assessment is carried out in section 6 and indicates that considerably more than one such family exhibited that pattern of names.

A.6 Probabilistic Independence

As we have seen, for mutually exclusive events probabilities add. Specifically, the probability of a disjunction of mutually exclusive events is the sum of the probabilities of the disjuncts. Thus, if $E_1, E_2, \ldots, E_n$ are mutually exclusive, $\mathbf{P}(E_1 \vee E_2 \vee \cdots \vee E_n) = \mathbf{P}(E_1) + \mathbf{P}(E_2) + \cdots + \mathbf{P}(E_n)$. Does a corresponding relationship hold for conjunction? For $E_1, E_2, \ldots, E_n$ arbitrary events such that no conjunction of them has zero probability, it follows from the definition of conditional probability that

$$\mathbf{P}(E_1 \,\&E_2 \,\& \cdots \&E_n) = \mathbf{P}(E_1) \times \mathbf{P}(E_2|\, E_1) \times \mathbf{P}(E_3|\, E_1 \,\&E_2) \times \cdots \times \mathbf{P}(E_\mathrm{n}|\, E_1 \,\&E_2 \,\& \cdots \&E_{n-1}).$$

To see this in the case of E_1 and E_2, note that

$$\begin{aligned}\mathbf{P}(E_1 \,\&E_2) &= 1 \times \mathbf{P}\,(E_1 \,\&E_2) \\ &= [\mathbf{P}(E_1)/\,\mathbf{P}(E_1)] \times \mathbf{P}(E_1 \,\&E_2) \\ &= \mathbf{P}(E_1) \times [\mathbf{P}\,(E_1 \,\&E_2)\,/\,\mathbf{P}(E_1)] \\ &= \mathbf{P}(E_1) \times \mathbf{P}(E_2|\, E_1)\end{aligned}$$

If, now, $\mathbf{P}(E_2|\, E_1) = \mathbf{P}(E_2)$, it follows that

$$\mathbf{P}(E_1 \,\&E_2) = \mathbf{P}(E_1) \times \mathbf{P}(E_2)$$

In that case, we say that E_1 and E_2 are probabilistically (or stochastically) independent. In general, we say that events $E_1, E_2, \ldots, E_n$ are independent if for all distinct events taken from this class, i.e., $E_{i_1}, E_{i_2}, \ldots, E_{i_\mathrm{k}}$, $1 \leq k \leq n$,

$$\mathbf{P}(E_{i_1} \,\&E_{i_2} \,\& \cdots \&E_{i_\mathrm{k}}) = \mathbf{P}(E_{i_1}) \times \mathbf{P}(E_{i_2}) \times \cdots \times \mathbf{P}(E_{i_\mathrm{k}}).$$

Events are probabilistically independent if they derive from causally independent processes. The converse, however, is not be true -- events can be probabilistically independent without being causally independent.

A.7 Equiprobability and Uniform Probability

In many situations, individual outcomes (elementary events) each have the same probability. In that case, if there are N possible outcomes, each outcome has probability $1/N$. Equiprobability in this sense is a special case of uniform probability in which isomorphic events under some equivalence relation have identical probability (see my 1990 article on uniform probability at http://www.designinference.com/documents /2004.12.Uniform_Probability.pdf).

A.8 The Fisherian Approach to Statistical Inferences

In Ronald Fisher's approach to hypothesis testing, one is justified in rejecting a chance hypothesis (cf. the hypothesis that the New Testament names found in the Talpiot tomb are likely to have occurred by chance) provided that a sample falls within a prespecified *rejection region* (also known as a *critical region*).[28] For example, suppose one's chance hypothesis is that a coin is fair. To test whether the coin is biased in favor of heads, and thus not fair, one can set a rejection region of ten heads in a row and then flip the coin ten times. In Fisher's approach, if the coin lands ten heads in a row, then one is justified rejecting the chance hypothesis.

Fisher's approach to hypothesis testing is the one most widely used in the applied statistics literature and the first one taught in introductory statistics courses. It was also the one used by the "Jesus Family Tomb" people. Nevertheless, in its original formulation, Fisher's approach is problematic: for a rejection region to warrant rejecting a chance hypothesis, the rejection region must have a small enough probability. The "Jesus Family Tomb" people, for instance, thought 1 in 600 was small enough. But why?

Given a chance hypothesis and a rejection region, how small does the probability of the rejection region have to be so that if a sample falls within it, then the chance hypothesis can legitimately be rejected? Fisher never answered this question. The problem here is to justify what is called a *significance level* such that whenever the sample falls within the rejection region and the probability of the rejection region given the chance hypothesis is less than the significance level, then the chance hypothesis can be legitimately rejected.

More formally, the problem is to justify a significance level α (always a positive real number less than one) such that whenever the sample (an event we will call E) falls within the rejection region (call it T) and the probability of the rejection region given the chance hypothesis (call it $\mathbf{H}$) is less than α (i.e., $\mathbf{P}(T|\mathbf{H}) < \alpha$), then the chance hypothesis $\mathbf{H}$ can be rejected as the explanation of the sample. In the applied statistics literature, it is common to see significance levels of .05 and .01. The problem to date has been that any such proposed significance levels have seemed arbitrary, lacking "a rational foundation."[29]

In *The Design Inference*, one of us (WmAD) shows that significance levels cannot be set in isolation but must always be set in relation to the probabilistic resources relevant to an event's occurrence.[30] In the context of Fisherian significance testing, probabilistic resources refer to the number opportunities for an event to occur. The more opportunities there are for an event to occur, the more possibilities there are for it to land in the rejection region. And this in turn means that there is a greater likelihood that the chance hypothesis under consideration will be rejected. It follows that a seemingly improbable event can become quite probable once enough probabilistic resources are factored in. In the case of the Talpiot tomb, the relevant probabilistic resources are the number of Jews living in Palestine around the time of Jesus—the greater this number, the more likely that the pattern of New Testament names found in that tomb could have arisen by chance.

A.9 Bayes's Theorem

Given an event E and chance hypotheses $\mathbf{H}_1$, $\mathbf{H}_2$, …, $\mathbf{H}_n$ that are mutually exclusive and exhaustive, the probability of any one of these hypotheses $\mathbf{H}_i$ given E is

$$\mathbf{P}(\mathbf{H}_i \mid E) = \frac{\mathbf{P}(E \mid \mathbf{H}_i)\mathbf{P}(\mathbf{H}_i)}{\mathbf{P}(E)}.$$

This is the simple form of Bayes's theorem (named after Thomas Bayes). Since $\mathbf{H}_1$, $\mathbf{H}_2$, …, $\mathbf{H}_n$ are mutually exclusive and exhaustive, it follows that the denominator here can be rewritten as

$$\begin{aligned}
\mathbf{P}(E) &= \mathbf{P}([E \,\&\, \mathbf{H}_1] \vee [E \,\&\, \mathbf{H}_2] \vee \cdots \vee [E \,\&\, \mathbf{H}_n]) \\
&= \mathbf{P}(E \,\&\, \mathbf{H}_1) + \mathbf{P}(E \,\&\, \mathbf{H}_2) + \cdots + \mathbf{P}(E \,\&\, \mathbf{H}_n) \\
&= \mathbf{P}(E|\mathbf{H}_1)\mathbf{P}(\mathbf{H}_1) + \mathbf{P}(E|\mathbf{H}_2)\,\mathbf{P}(\mathbf{H}_2) + \cdots + \mathbf{P}(E|\mathbf{H}_n)\,\mathbf{P}(\mathbf{H}_n)
\end{aligned}$$

These equalities follow simply from unpacking the axioms of probability and the definition of conditional probability. Substituting this last expression for the denominator in the simple form of Bayes's theorem now yields the standard form of Bayes's theorem:

$$\mathbf{P}(\mathbf{H}_i \mid E) = \frac{\mathbf{P}(E \mid \mathbf{H}_i)\mathbf{P}(\mathbf{H}_i)}{\mathbf{P}(E \mid \mathbf{H}_1)\mathbf{P}(\mathbf{H}_1) + \mathbf{P}(E \mid \mathbf{H}_2)\,\mathbf{P}(\mathbf{H}_2) + \cdots + \mathbf{P}(E \mid \mathbf{H}_n)\,\mathbf{P}(\mathbf{H}_n)}.$$

A.10 The Bayesian Approach to Statistical Inferences

In Bayesian statistical inference, one considers an event E and two competing hypotheses $\mathbf{H}_1$ and $\mathbf{H}_2$. Think of $\mathbf{H}_1$ as the hypothesis that the Talpiot tomb belonged to the New Testament Jesus and $\mathbf{H}_2$ as the hypothesis that the pattern of New Testament names in the Talpiot tomb occurred by chance. Moreover, think of the event E as evidence for either of these hypotheses. To decide whether the evidence E better supports either $\mathbf{H}_1$ or $\mathbf{H}_2$ therefore amounts to comparing the probabilities $\mathbf{P}(\mathbf{H}_1|E)$ and $\mathbf{P}(\mathbf{H}_2|E)$ and determining which is bigger. These probabilities are known as *posterior probabilities* and measure the probability of a hypothesis given the event/evidence/data E.

Posterior probabilities cannot be calculated directly but must rather be calculated on the basis of Bayes's theorem. Using the simple form of Bayes's theorem, we find that the posterior probability $\mathbf{P}(\mathbf{H}_i|E)$ ($i = 1$ or 2) is expressed in terms of $\mathbf{P}(E|\mathbf{H}_i)$, known as the *likelihood* of $\mathbf{H}_i$ given E, and $\mathbf{P}(\mathbf{H}_i)$, known as the *prior probability* of $\mathbf{H}_i$. Often prior probabilities cannot be calculated directly. Moreover, in calculating the posterior probability, we still need to compute the denominator in the simple form of Bayes's theorem, namely, $\mathbf{P}(E)$.

Fortunately, this last term does not need to be calculated. Because the aim is to determine which of these hypotheses is better supported by the evidence E, it is enough to form the ratio of posterior probabilities

$$\frac{\mathbf{P}(\mathbf{H}_1 \mid E)}{\mathbf{P}(\mathbf{H}_2 \mid E)}$$

and determine whether it is greater than or less than 1. If this ratio is greater than 1, it supports the hypothesis in the numerator ($\mathbf{H}_1$, which we are treating as the “Talpiot equals Jesus tomb” hypothesis). If it is less than 1, it supports the hypothesis in the denominator ($\mathbf{H}_2$, which we are treating as the “Talpiot names occurred by chance” hypothesis).

This ratio, using the simple form of Bayes’s theorem, can now be rewritten as follows (note that the denominator in Bayes’s theorem simply cancels out):

$$\frac{\mathbf{P}(\mathbf{H}_1 \mid E)}{\mathbf{P}(\mathbf{H}_2 \mid E)} = \frac{\mathbf{P}(E \mid \mathbf{H}_1)}{\mathbf{P}(E \mid \mathbf{H}_2)} \times \frac{\mathbf{P}(\mathbf{H}_1)}{\mathbf{P}(\mathbf{H}_2)}$$

The first factor on the right side of the equation is known as the *likelihood ratio*; the second is the ratio of priors, which measures our relative degree of belief in these two hypotheses before E entered the picture. Since the ratio on the left side of this equation represents the relative degree of belief in these two hypotheses once E is taken into account, this equation shows that updating our prior relative degree of belief in these hypotheses (i.e., before the evidence E was factored in) is simply a matter of multiplying the ratio of prior probabilities times the likelihood ratio.

In this way, the likelihood ratio, i.e.,

$$\frac{\mathbf{P}(E \mid \mathbf{H}_1)}{\mathbf{P}(E \mid \mathbf{H}_2)},$$

is said to measure the strength of evidence that E provides for $\mathbf{H}_1$ in relation to $\mathbf{H}_2$. Thus, since we are treating $\mathbf{H}_1$ as the “Talpiot equals Jesus tomb” hypothesis and $\mathbf{H}_2$ as the “Talpiot names occurred by chance” hypothesis, if this ratio is bigger than 1, E favors the former hypothesis and supports that the New Testament Jesus really was buried in the Talpiot tomb. On the other hand, if this ratio is less than 1, it favors the latter hypothesis and therefore supports that someone else is buried there.

Endnotes

[1]See http://www.jesusfamilytomb.com/evidence/probability.html (last accessed June 15, 2007).

[2]Simcha Jacobovici and Charles Pellegrino, *The Jesus Family Tomb: The Discovery, the Investigation, and the Evidence That Could Change History* (San Francisco: Harper, 2007), 115.

[3]See http://fisher.utstat.toronto.edu/andrey/OfficeHrs.txt (last accessed June 18, 2007).

[4]Actually, the genitive of this name (transliterated "Mariamenou") appears in the tomb on an ossuary, and it is combined with another appellation, "e Mara." The "Jesus Family Tomb" people refer to it inaccurately as "Mariamne." For the sake of argument, we won't quibble with this usage.

[5]See the video short at http://www.jesusfamilytomb.com/evidence/probability/jesus_equation.html (last accessed June 25, 2007).

[6]Christopher Mims, "Should You Accept the 600-to-One Odds That the Talpiot Tomb Belonged to Jesus?" *Scientific American* 296 (March 2007): available online at http://sciam.com/article.cfm?articleID =14A3C2E6-E7F2-99DF-37A9AEC98FB0702A (last accessed June 27, 2007).

[7]Tal Ilan, *Lexicon of Jewish Names in Late Antiquity: Palestine 330 BCE – 200 CE*, Texts & Studies in Ancient Judaism, 91 (Tübingen : Mohr Siebeck, 2002).

[8]These numbers are taken from what, at the time of this writing, is the most exact statement of the Jesus equation as given by Andrey Feuerverger in his paper addressed to the statistical community: http://fisher.utstat.toronto.edu/andrey/OfficeHrs.txt (last accessed June 28, 2007).

[9]Within families, names are not probabilistically independent—sons, for instance, may be more likely to be named after fathers; moreover, sons of the same father are unlikely to receive the same name (George Foreman naming all his sons George is the exception). But across families, independence seems a reasonable assumption. And even within families, this assumption seems approximately true. In any case, we do not dispute this assumption. The problems with the Jesus equation go much deeper.

[10]See http://www.jesusfamilytomb.com/the_tomb/james_ossuary.html (last accessed June 30, 2007) as well as an analysis of the patina on the James ossuary that is supposed to have the same spectral signature between pages 110 and 111 in Jacobovici and Pellegrino, *Jesus Family Tomb*.

[11]Jacobovici and Pellegrino, *Jesus Family Tomb*, 114.

[12]Ibid.

[13]In fact, all the Marys in the New Testament are referred to with the commonest Greek form of that name: in addition to Mary the mother of Jesus and Mary Magdalene, there is Mary the mother of James and Joses, Mary the wife of Cleophas, and Mary the sister of Lazarus and Martha.

[14]For the *Acts of Philip*, go here: http://www.newadvent.org/fathers/0818.htm (last accessed July 3, 2007).

[15]For the *Gospel of Philip*, go here: http://www.gnosis.org/naghamm/gop.html (last accessed July 3, 2007).

[16]François Bovon, "The Tomb of Jesus," statement to the Society of Biblical Literature Forum

[17]Richard Bauckham, "The Names on the Ossuaries," in *Buried Hopes or Risen Savior*, ed. Charles Quarles (Nashville: Broadman & Holman, forthcoming).

[18]Jacobovici and Pellegrino, *Jesus Family Tomb*, 114.

[19]As a gauge on the number of families near Jerusalem during that time, the "Jesus Family Tomb" people estimate that "only 80,000 males lived in Jerusalem during the time period of ossuary use." Ibid., 77.

[20]"Knowledge of the number of clergy is not without importance in estimating the size of the Palestinian population at the time of Jesus. . . . The priests and Levites, with women and children, would number about 50,000 to 60,000. The priests and Levites returning from exile with Joshua and Zerrubbabel

made up about one-tenth of the entire community (Ezra 2.36–42, cf. 2.64; Neh. 7.39–45, 66), a generally credible proportion. Thus, Palestine in the time of Jesus had a Jewish population of 10 x 50,000 (or 60,000), about 500,000 or 600,000. In my opinion, this is a more likely number than the million often assumed." Quoted from Joachim Jeremias, *Jerusalem in the Time of Jesus: An Investigation into Economic and Social Conditions During the New Testament Period* (Philadelphia: Fortress, 1969), 205. A more recent estimate likewise sets the number at 500,000: "By the first century the Jewish population of Palestine had grown massively, perhaps to as much as 500,000. . . . The size of the population of ancient Palestine cannot be determined, but 500,000 is a plausible figure for the population of the Palestinian interior." Quoted from Seth Schwartz, *Imperialism and Jewish Society, 200 B.C.E. to 640 C.E.* (Princeton: Princeton University Press, 2001), 11, 41.

[21]"For about a hundred years, from 30 BCE to 70 CE, people in the Jerusalem area practiced a specific form of 'secondary burial' involving small limestone ossuaries." Quoted from the "Jesus Family Tomb" website: http://www.jesusfamilytomb.com/essential_facts/ossuaries.html (last accessed July 6, 2007).

[22]See William Feller, *An Introduction to Probability Theory and Its Applications*, volume 1, 3rd ed. (New York: Wiley, 1968), 167–169.

[23]Andrey Feuerverger assumes that there were "five million Jews who lived during that era." See Christopher Mims, "Should You Accept the 600-to-One Odds That the Talpiot Tomb Belonged to Jesus?" *Scientific American* 296 (March 2007): available online at http://sciam.com/article.cfm?articleID =14A3C2E6-E7F2-99DF-37A9AEC98FB0702A (last accessed June 27, 2007).

[24]See Feller, *Introduction to Probability*, 148.

[25]These results about binomial distributions may be found in any introductory probability or statistics text. See, for instance, Feller, *Introduction to Probability*, 147–150, 223.

[26]That these probabilities should be, relatively speaking, so large may seem startling to the uninitiated, but comes about because of the way combinatorial factors can increase seemingly small probabilities. If, for instance, you walk into a room with 252 other people, you have an even chance of finding someone with the same birthday as yours. If, on the other hand, you walk into a room with 22 other people, you have an even chance of finding some pair of people in the room that share a birthday. This is known as the birthday paradox, and the much larger probability of some pair of people in a group sharing a birthday rather than somebody in the group matching a fixed birthday results from the former probability factoring in all the combinatorial ways of matching different people. In a room with 23 people (cf. the group of 22 other people plus yourself), there are 253 (cf. the group of 252 other people plus yourself) ways to match up people. For the birthday paradox, see Feller, *Introduction to Probability*, 33.

[27]"After listening to filmmaker Simcha Jacobovici explain the so-called 'Jesus equation', you'll realize just how *unlikely* it is that this *isn't*, in fact, his tomb." In our terminology, **P**(**J**) is large and **P**(**~J**) is small. Quoted from http://www.jesusfamilytomb.com/evidence/probability.html (last accessed June 15, 2007).

[28]For a brief summary of Fisher's views on tests of significance and null hypotheses, see Ronald A. Fisher, *The Design of Experiments* (New York: Hafner, 1935), 13–17.

[29]Colin Howson and Peter Urbach, *Scientific Reasoning: The Bayesian Approach*, 2nd ed. (LaSalle, Ill.: Open Court, 1993), 178. For a similar criticism see Ian Hacking, *Logic of Statistical Inference* (Cambridge: Cambridge University Press, 1965), 81–83.

[30]William A. Dembski, *The Design Inference: Eliminating Chance Through Small Probabilities* (Cambridge: Cambridge University Press, 1998), ch. 6.