Evaluating Competing Hypotheses with Bayes' Theorem: Qumran as a Case Study

Evaluating Competing Hypotheses with Bayes' Theorem: Qumran as a Case Study[1]

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Abstract

This article seeks to provide a new approach to the classic problem of determining the function of the community in Qumran. It considers three hypotheses concerning the function of the community at Qumran, and attempts to assign a probability to each using a Bayes' theorem calculation in four steps: (1) Establish and list available data related to the hypotheses. (2) Numerically assess the data to establish data probabilities. (3) Establish prior probabilities. (4) Calculate posterior probabilities with Bayes' theorem. The results of this calculation indicate a 36% probability that Qumran was an Essene community; 21% probability that Qumran was a military post; and 43% probability that Qumran was a commercial post.

Keywords : Bayes' Theorem Qumran Hypothesis Dead Sea Scrolls Essenes

1. Introduction

The Dead Sea Scrolls---the fascinating manuscripts of the Hebrew Bible, its commentaries, and sectarian doctrines---were found in the caves near Qumran. The site, overlooking the Dead Sea, had a settlement that has been the focal point of controversy. What was the function(s) of the settlement between the first century B.C.E. and 68 C.E.? Various opinions have been proposed for this question. De Vaux (1973), the excavator of Qumran, thinks that the site was an isolated religious community of the Essenes. Golb suggests a military post, or fortress (1985;1994), while Crown & Cansdale favor the idea of a commercial entrepôt (1994).

In orthodox evaluation of the function of Qumran, attempts to establish the normative

[1] I would like to express my gratitude to Dr. Steven Olson for reviewing this article and suggesting necessary corrections for improvement.

Essenes are confronted by various difficulties: Philo seems to have used secondary information; Pliny's description of the location of the Essenes creates scholarly debates and fails to decide whether the Essenes were settled at Qumran or the vicinity of Ein Gedi; and information provided by Josephus suffers from contradictory statements. Whether Sadducees or Essenes wrote the scrolls cannot be determined with certainty and it is possible that the scrolls have nothing to do with the Qumran settlement. Consideration of pottery, locus 30, cave 8(3Q), and the cemetery of Qumran cannot provide a definitive answer.

Because orthodox discussion fails to bring a definitive answer and generates endless controversy, we seek a theoretical background from philosophical considerations. The hypothetico-deductive method does not deal with disputes about the relative merits of competing hypotheses. This renders the method a less favorable option to approach our problem. The classical idea of probability, identified with the principle of indifference, states that if there is no reason to favor one case over another we can consider them to be equally probable. Probabilities may be classified as either objective or subjective. Theories of objective probability can be categorized into three opinions: frequency theories that identify probabilities with relative frequencies, limiting frequency theories that regard probabilities as limits of relative frequencies, and hypothetical frequency theories that consider probabilities to be limits of relative frequencies in virtual sequences. Subjective probability, on the other hand, identifies probabilities with degrees of belief, constrained only by the probability calculus. We seem to be using not only subjective probability but also mixed physical/epistemic probability, which can be obtained by direct inference from indefinite probabilities. Bayes' theorem incorporates subjective judgments into calculation as prior probabilities, and produces the result as posterior probabilities. This enables us to evaluate competing hypotheses within the framework of subjective probability.

The experimental procedure to evaluate competing hypotheses, using Qumran as a case study, contains four steps: (1) Establish and list available data related to Qumran function hypotheses; (2) Numerically assess the data to determine data probabilities $P(D \mid H_k)$; (3) Establish prior probabilities $P(H_k)$; and (4) calculate posterior probabilities $P(H_k \mid D)$ using Bayes' theorem. Thereby, we attempt to provide the probability for each hypothesis of the function of the Qumran settlement.

2. Bayes' Theorem

The name Bayesian comes from the English clergyman Thomas Bayes, whose

paper in 1763 contained a version of what is now called as Bayes' Theorem. The basis of the theorem is that the joint probability of two events H and D can be written as the product of the probability of one of the events and conditional probability of the second event, given the first:

$$P(H \cap D) = P(H) \cdot P(D \mid H)$$

We can also write the joint probability of the two events by reversing the two events:

$$P(D \cap H) = P(D)P(H|D)$$

The two right sides are equal because the two left sides are equal. Equating the right sides with some rearrangement produces:

$$P(H \mid D) = \frac{P(D \mid H)P(H)}{P(D)}$$

Events $H_1, H_2, \ldots, H_i$ are said to form a partition of the sample space if each possible outcome in the sample space belongs to exactly one of the H_k's. In this case, we can write the probability of D in the denominator as a weighted sum of the conditional probabilities P ($D \mid H_k$) where the weights are P (H_k). The equation for the event $P(H_k)$ becomes (Iversen 1984:12):

$$P(Hk \mid D) = \frac{P(D \mid Hk)P(Hk)}{P(D \mid H_1)P(H_1) + \ldots + P(D \mid H_i)P(H_i)}$$

for each k between 1 and i. This formula can be rewritten as follows (Howson & Urbach 1993:28):

$$P(H_k \mid D) = \frac{P(D \mid H_k)P(H_k)}{\sum P(D \mid H_i)P(H_i)}$$

P($H \mid D$) is the posterior probability, the probability of the hypothesis H conditioned on the data D. P($D \mid H$) is the likelihood of the hypothesis, i.e., the probability of the data D conditioned on the hypothesis H. P(H) is the prior probability, the probability of the hypothesis.

An application of Bayes' theorem is the following. Suppose that we have three different hypotheses, H_1, H_2, and H_3, and we want to know the probabilities of the hypotheses given the data, that is, the posterior probabilities P($H_1 \mid D$), P($H_2 \mid D$), and P($H_3 \mid D$). First, we express our subjective opinion for each hypothesis. For instance, we may think that the probabilities of H_1, H_2, and H_3 are 0.7, 0.1, and 0.2 respectively. These are prior probabilities $P(H_1) = 0.7$, $P(H_2) = 0.1$, and $P(H_3) = 0.2$. Next, we need to know the three data probabilities, P($D \mid H_1$), P($D \mid H_2$), and P($D \mid H_3$). Suppose we determine P($D \mid H_1$) = 0.7, P($D \mid H_2$) = 0.2, and P($D \mid H_3$) = 0.5 (Iversen 1984:13). (The data probabilities that we assign in actual practice may be subjective. This will be discussed later). Therefore, the three data probabilities are:

$$P(D \mid H_1) = 0.7$$

$$P(D \mid H_2) = 0.2$$

$$P(D \mid H_3) = 0.5$$

Using Bayes' theorem we get:

$$P(H_1 \mid D) = \frac{P(D \mid H_1)P(H_1)}{P(D \mid H_1)P(H_1) + P(D \mid H_2)P(H_2) + P(D \mid H_3)P(H_3)}$$

$$= \frac{(0.7)(0.7)}{(0.7)(0.7) + (0.2)(0.1) + (0.5)(0.2)}$$

$$= 0.803$$

$$P(H_2 \mid D) = \frac{P(D \mid H_2)P(H_2)}{P(D \mid H_1)P(H_1) + P(D \mid H_2)P(H_2) + P(D \mid H_3)P(H_3)}$$

$$= \frac{(0.2)(0.1)}{(0.7)(0.7) + (0.2)(0.1) + (0.5)(0.2)}$$

$$= 0.033$$

$$P(H_3 \mid D) = \frac{P(D \mid H_3)P(H_3)}{P(D \mid H_1)P(H_1) + P(D \mid H_2)P(H_2) + P(D \mid H_3)P(H_3)}$$

$$= \frac{(0.5)(0.2)}{(0.7)(0.7) + (0.2)(0.1) + (0.5)(0.2)}$$

$$= 0.164$$

These are the posterior probabilities. They remind us that, after considering the data, we have the probability of 0.80 that the data support H_1, 0.03 that they support H_2, and 0.16 that they support H_3 (Iversen 1984:13-14).

A table is useful to conveniently arrange computations like these.

Example of Computation (c.f. Iversen 1984:15)

Hypothesis H	Prior Probabilities $P(H_k)$	Data Probabilities $P(D \mid H_k)$	Product $P(D \mid H_k)P(H_k)$	Posterior Probabilities $P(H_k \mid D)$
1	0.7	0.7	0.49	0.803
2	0.1	0.2	0.02	0.033
3	0.2	0.5	0.1	0.164
	Sum 1.00		Sum 0.62=P(D)	Sum 1.00

The first column identifies the hypotheses. The second column gives the prior probabilities,

and the sum of the numbers in this column is always 1.00. The third column gives the probabilities of the data depending on the hypotheses. The fourth column gives the product of the data probability and the prior probability for each hypothesis. Bayes' theorem uses each of these three products as the numerator, and the sum of the products as the denominator. The last column shows the results of dividing each product in the fourth column by the sum of the products, i.e., the posterior probabilities (Iversen 1984:14).

According to Howson & Urbach, the simple interpretation of the results would be: (1) when $P(H \mid D) > P(H)$, D conforms or supports H; (2) when $P(H \mid D) < P(H)$, D disconfirms or undermines H; and (3) when $P(H \mid D) = P(H)$, D is neutral with respect to H(1993:117). Thus, if we are trying to select one hypothesis, we conclude that D supports H_1 and that D undermines H_2 and H_3. We can also simply accept the numerical values of the posterior probabilities as they are and describe the probabilities for each hypothesis: the posterior probabilities of H_1, H_2, and H_3 are 80.3 %, 3.3 %, and 16.4 % respectively. Because we are seeking to avoid endless controversies, the latter presentation will be preferable.

In the Bayesian approach, prior probabilities are a subjective quantification of judgments or opinions. In other words, the prior probabilities specified by one person may differ from those by another (Morgan 1968:3). This idea of subjectivity was anathema for scholars interested in statistics as a mathematical system[2]; i.e., Hamaker (1977:11) stated that adoption of the Bayesian approach "may seal the doom of applied statistics as a respectable and respected profession." However, as Moore (1978:73) and Good (1978:65) respond, it is not truthful to say that this is not expert statistics and to sweep away subjectivism. Nearly all of statistical analysis contains some subjective elements. For instance, in the event of tossing a coin, we assign a probability of one-half to heads. The underlying assumption is that it is a fair coin and that the manner of tossing is random so as not to influence the result. The classical statistical approach has attempted to minimize such subjective elements (Morgan 1968:3).

The Bayesian approach, on the other hand, attempts to constructively use subjective judgments that are vital for any reasonable statistical thinking. It quantifies certain judgments and formally incorporates them in the analysis (Pollard 1986:12). It reflects the fact that when opinions of

[2] The reason why the opponents of the Bayesian method claim that the method is not justified is that it does not conform to the particular theory of probability (perhaps objective probability) they advocate---it is in the framework of subjective probability that the Bayesian method is justified (Weatherford 1982:226). I would also indicate that law and order archaeologists will be indifferent to the method because it does not conform to generalization and objectivity.

two people are different, these opinions will be modified differently by the same limited facts because prior convictions often influence the way people see the facts. Since researchers have different training and experience, they may also assign different prior probabilities to the same problem. The prior probabilities allow everyone to see the subjective aspects of the analysis and force the analyst to express personal opinion and biases. This, as Iversen indicates, actually makes the whole analysis less subjective (1984:67). Making subjectivity explicit rather than trying to disregard it may be the way to bring us closer to objectivity.

Bayes' theorem incorporates subjective judgments into calculation as prior probabilities, and produces the result as posterior probabilities. This enables us to evaluate competing hypotheses within the framework of subjective probability. It is this procedure, I contend, that our discipline needs to utilize if we are to establish the concept that generates numerical data, evaluate hypotheses, and moves toward historical reconstruction. A case study may be necessary to justify this claim.

3. Experimental Procedure to Solve the Qumran Problem

In the previous section, I have shown that applying Bayes' theorem to the data may have a great potential of establishing a common ground for evaluating hypotheses. The question is whether we can really apply the theorem to the problem of Qumran, namely, evaluating the three possible functions.

In order to obtain posterior probabilities $P(H_k \mid D)$, Bayes' theorem requires prior probabilities $P(H_k)$ and data probabilities $P(D \mid H_k)$. Prior probabilities are subjective quantification of judgments regarding hypotheses, and they can be obtained relatively easily---we simply express our opinion according to the probability calculus. It is better to have numerical data probabilities in the first place, but obviously they are not in hand. This makes it necessary to assign probability of data given hypothesis to each available evidence. This process of assigning quantification to data is subjective, and we need to enclose available data as a kind of closed-system so that we can have less difficulty in quantifying our subjective judgments. Once the requirements are fulfilled, we are ready to calculate posterior probabilities; the calculation requires only high school mathematics.

Thus, our procedure is to:

(1) Establish and list available data related to Qumran function hypotheses. Treat the data in an enclosure, or closed-system.

(2) Numerically assess the data to establish data probabilities $P(D \mid H_k)$.

(3) Establish prior probabilities $P(H_k)$.

(4) Calculate posterior probabilities $P(H_k \mid D)$ with Bayes' theorem.

3.1 Descriptive Information as a Closed-System

As described above, information related to the function of Qumran can be divided into three categories: (1) written records of ancient writers, (2) the Dead Sea scrolls, and (3) the results (if any) of the excavation. First of all, we will list data from each category to begin the proposed procedure.

3.1.1 Category 1 or System 1

The Essenes have been described by Philo, Pliny, and Josephus. Philo describes the Essenes as agriculturalists: "There are farmers among them, experts on the art of sowing and cultivating plants, shepherds leading every sort of flock, and beekeepers." (*Apologica pro Judaeis* 8)

Pliny records "the Essenes have only palm trees for company① and the town of Ein Gedi...lies below② the Essenes...now like the other place (e.g. Jerusalem) a heap of ashes③." (*Natural History* 5.17.73) ① implies the isolated character of the Essene community. The meaning of ② depends on the word "below," which means either (1) lower altitude or (2) south. (1) If Ein Gedi lies lower than the Essenes, the Essenes must have been living above Ein Gedi, perhaps in caves. This is supported by the fact that when "below" was used, Pliny generally meant at an altitude lower than something else. (2) If Ein Gedi is south of the Essenes, the community must have been Qumran, a notable site northward. This is supported by the claim that Pliny indeed used the word "below" to describe places in a sequence. In fact, Pliny mentions Masada in the next sentence, "Next comes Masada, a fortress on a rock....", thereby completing a sequence from the Essenes (Qumran), Ein Gedi, to Masada. ③The statement of Ein Gedi being "heap of ashes" brings us to two options. (1) Pliny knew the fate of Qumran. The people living at Qumran could not have been the Essenes because Roman soldiers occupied Qumran after 70 C.E. and because the statement could only have been written after the fall of Jerusalem. (2) Pliny did not know the fate of Qumran. Pliny simply recorded what he heard: the Essenes were living at Qumran for centuries.

Josephus describes the characteristics of the Essenes as follows:

① They scorned wealth and held no private property: "They despise riches...It is the law that those who enter the sect shall surrender their property to the order" (*War* 2.122). ② They were Sabbath observants: "They are forbidden, more rigorously than any other Jew, to attend to their work on the seventh day" (*War* 2.147). ③They opposed slavery: "They acquire no slaves...they consider slavery on injustice" (*Antiquities* 18.21). ④ They were celibate: "They take no wives" (*Antiquities* 18.21).[3]

Josephus also mentions a branch of the Essenes that permitted marriage for the propagation of the species: "There exists another order of Essenes who...marry women...because it is necessary to have children" (*War* 2.160-161). ⑤ They rejected oaths: "They refrain from swearing, considering it worse than perjury" (*War* 2.135). ⑥ They were politically indifferent (*Antiquities* 18.1.18) although a certain John the Essene was in charge of the Jewish troops in Thamnia, Lydda, Joppa, and Emmaus in the First Revolt against the Romans (*War* 2.20.2).

Therefore, Essene characteristics according to Philo, Pliny, and Josephus are:

Philo	agriculturalists	
Pliny	isolation	
	location of Essenes the meaning of "below"	lower altitude → the vicinity of Ein Gedi, caves?
		south → Qumran
	the fate of Ein Gedi & Qumran	Pliny knew → Qumranites, not the Essenes
		Pliny did not know → tourist information
Josephus	no private property	
	Sabbath observants	
	opposed to slavery	
	celibate	no wives
		some accepted marriage
	rejected oath	
	politically indifferent	

3.1.2 Category 2 or System 2: the Dead Sea scrolls

A circular argument, Schiffman states, has supported the identification of the Essenes with the Qumran: "If the sectarian materials in the Dead Sea texts could be identified with the Essenes, then all information by Philo, Pliny, and Josephus could be read into and harmonized with the evidence of the scrolls. And if the scrolls were Essene, then they could in turn be used to interpret the material in Philo, Pliny, and Josephus" (1992:39-40). The circular argument works out as follows:

Stage ①: the Dead Sea scrolls are of the Essenes.

Stage ②: the records of Philo, Pliny, and Josephus are harmonized with the scrolls.

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[3] Celibacy is also mentioned by Philo (*Apologia pro Judaeis* 14) and Pliny (*Natural History* 5.15.73).

Stage ③: the scrolls are used to interpret the records of Philo, Pliny, and Josephus.

This indicates that the assumption that the scrolls were written by the Essenes will result in complex textual arguments and unending controversies, and we seem to have both at present.

In order to solve the question of the function of Qumran, instead of immersing ourselves in textual criticism, we need to ask who wrote the Dead Sea scrolls and who hid them in the caves nearby Qumran. The first question can be divided into two options: (1) the Essenes wrote them and (2) the Sadduceans did.[4] To streamline the process, we simply list the two options at this time. The second question can be answered in two ways: either Qumranites hid the scrolls or non-Qumranites did. If (1) the Essenes wrote the scrolls, this leads to ①that Qumranites hid them and Qumran was related to the Essenes or ②that non-Qumranites did and Qumran was not related to the Essenes. The scrolls were brought in to avoid Roman conquest or for final storage as *genizah*. If (2) the Sadduceans wrote the scrolls, this leads to ①that Qumranites hid them and Qumran was related to the Sadduceans[5] or ②that non-Qumranites did and Qumran was not related to the Sadduceans. Therefore, category 2 related to the Dead Sea scrolls is:

Who wrote the Dead Sea Scrolls?	Essenes wrote the scrolls
	Sadduceans wrote the scrolls

Who hid the scrolls?	Qumranites hid the scrolls	Qumran was related to the Essenes Essenes wrote the scrolls
		Qumran was related to the Sadduceans Sadduceans wrote the scrolls
	non-Qumranites hid the scrolls	Qumran was not related to the Essenes Essenes wrote the scrolls
		Qumran was not related to the Sadduceans Sadduceans wrote the scrolls

4 This question itself can become a topic for hypotheses evaluation using Bayes' theorem; i.e., ① set up prior probabilities for each option; ② determine data probabilities for textual arguments; and ③ calculate posterior probabilities with Bayes' theorem to obtain probabilities for each option. But, this is beyond the scope of this paper.

5 Surprisingly, in theory, Qumran could have functioned as the Sadducean community.

3.1.3 Category 3 or System 3: Archaeological Evidence

Four lines of evidence will be considered in this category: pottery, locus 30, cave 8(3Q), and the cemetery. (1) It has been claimed that pottery found in the caves was identical with that of the Qumran settlement. An installation, possibly a potter's workshop, was also found at the settlement. This leads to two options: ①Qumranites used the jars to hide the scrolls; and ②non-Qumranites borrowed the jars to hide the scrolls. Undecorated plain pottery assemblages of Qumran form a contrast with richer and varied assemblages of other Judean sites, although Qumran does have "luxury" items such as glass wares. This leads to ①that Qumranites practiced a deliberate isolation; or ②that the geographical location of the site simply made the inhabitants produce their own plain pottery.

(2) Locus 30 has been considered to be a *scriptorium*, where the scrolls were supposedly copied. This was based on inkwells and stuccoed furniture in this locus, which De Vaux interpreted as desks. Recent study, however, revealed that there was no relation between the inkwells and stuccoed furniture. The inkwells were found on the floor. The ceiling had burnt and fallen over the floor and its contents (including the inkwells), forming over it a thick layer that contained the stuccoed furniture. This leads to that ①that locus 30 was still a *scriptorium*, used for copying the scrolls; or that ② that the locus was misinterpreted and might have been a *triclinia*, a dining room.

(3) In cave 8 (3Q), the portions of the copper scroll describing hiding places of secret treasure were found, hidden behind a rock, away from the remnants of 14 manuscripts. The jars containing the manuscripts were simply heaped behind the rock. The cave is 2km north of Qumran. This leads to two options: ①there is no connection between the manuscripts and the copper scroll. Different people used the cave. The manuscripts came from Qumran. The copper scroll was from somewhere else. ②Neither the copper scroll nor the manuscripts came from Qumran. The cave was used as a *genizah*.

(4) With respect to the Qumran cemetery, we seem to have a circular argument. De Vaux excavated 41 of 1200 graves (nine more by Steckoll). The excavated tombs consisted of thirty-six male, nine female, and six children (one with its mother). According to De Vaux, one woman's grave in the main cemetery is in a position apart from the general alignment and is a different type from the rest and that six other tombs of women and four of children are situated either in the secondary cemeteries or the extensions of the main cemetery (1973:128-129). However, an aerial photograph of Qumran clearly shows that there is only one cemetery following the natural topography eastward from the settlement. Topography dictated the shape of the cemetery into four prongs that were regarded by De Vaux as secondary cemeteries. Thus, the circular argument worked out as follows:

Stage ①: the Qumran settlement was of the Essenes.

Stage ②: the records of Philo, Pliny, and Josephus that described the Essenes as celibate are harmonized with the results of the excavation.

Stage ③: the excavation results are used to assure the records of the three.

We, then, have three options regarding the secondary cemeteries. (1) Secondary cemeteries still exist. The presence of women can be trivial. Qumran was basically a celibate community. (2) Secondary cemeteries do not exist. There seems to have been significant presence of women at the settlement. This leads to ①that the settlement was inhabited by a branch of Essenes that accepted marriage; or ②that the Essenes never lived at the settlement because it had nothing to do with celibate Essenes. (3) We withhold our conclusion because only a few percent of the tombs have been excavated.

Therefore, category 3 related to archaeological evidence is as follows:

<table>
<tr><td rowspan="2">Pottery</td><td>Identical at the caves and the settlement
Potter's workshop at the settlement</td><td colspan="2">1.Qumranites used the jars to hide the scrolls.

2.Non-Qumranites borrowed the jars to hide the scrolls.</td></tr>
<tr><td>Undecorated plain assemblages at Qumran distinct from other Judean sites Some "luxury" items</td><td colspan="2">1.Qumranites practiced the deliberate isolation.

2.Location made the settlers produce their own pottery.</td></tr>
<tr><td rowspan="2">Locus 30</td><td rowspan="2">There are no relations between ink wells and the stuccoed furniture.</td><td colspan="2">1.The locus was scriptorium.</td></tr>
<tr><td colspan="2">2.The locus may be a dining room.</td></tr>
<tr><td rowspan="2">Cave8(3Q)</td><td rowspan="2">The copper scroll and 14 manuscripts (away from it) were found.

3Q is 2km away from Qumran.</td><td colspan="2">1. No connection beween the copper scroll & manuscripts.
Different people used the cave.
The manuscripts are from Qumran; the copper scroll from somewhere.</td></tr>
<tr><td colspan="2">2.None of them are from Qumran. The cave was genizah.</td></tr>
<tr><td rowspan="2">Cemetery</td><td rowspan="2">50 tombs out of 1200 were excavated.

Women's graves are different from norm(?); the secondary cemeteries are supposed to explain that.</td><td colspan="2">1.Secondary cemeteries exist.
Qumran was basically celibate.</td></tr>
<tr><td>2.Secondary cemeteries do not exist</td><td>1.A branch of Essenes that accepted marriage was at Qumran.</td></tr>
</table>

	Aerial photo shows prongs (secondary cemeteries?) of the main cemetery dictated by topography.		2.The Essenes never lived at Qumran, which had nothing to do with celibacy.
		3.The tombs excavated are too few to draw conclusion.	

3.2 Numerical Assessment of Data

In the previous, we have established and listed available data relating the Qumran function hypotheses. In this section, we attempt to determine data probabilities $P(D \mid H_k)$ and also experiment with weighted treatment of the data to allow specific data to be more significant than others.

3.2.1. Establishing Data Probabilities $P(D \mid H_k)$

For example, the first item of category 1 is "Essenes were agriculturalists." We will assign the probability of data given hypotheses for this item. I assign 0.3 to the probability of data given hypothesis 1: Qumran was the Essene community. Similarly, I assign 0.7 to the probability of data given hypothesis 2: Qumran was a military post, and 0.7 to the probability of data given hypothesis 3: Qumran was a commercial post. Rationale of my decision is that if Qumran had been the Essene community, performing agriculture around the site would have been difficult, but if Qumran had been a military or commercial post, the Essenes would have lived somewhere that could make it possible to practice agriculture. Using mixed physical/epistemic probability, my mind worked as follows:

With regard to H_1: Qumran was the Essene community,

(1) The probability of people being agriculturalists at Qumran is 0.3.

(2) I am justified in believing that the Essenes were agriculturalists at Qumran.

(3) The probability of Essenes being agriculturalists given that Qumran was an Essene community is 0.3, $P(D \mid H_1)$.

With regard to H_2: Qumran was a military post,

(1) The probability of people being agriculturalists at place like Ein Gedi is 0.7.

(2) I am justified in believing that the Essenes were agriculturalists at a place like Ein Gedi.

(3) The probability of Essenes being agriculturalists given that Qumran was a military post is 0.7, $P(D \mid H_2)$.

With regard to H_3: Qumran was a commercial post,

(1) The probability of people being agriculturalists at a place like Ein Gedi is 0.7.

(2) I am justified in believing that the Essenes were agriculturalists at a place like Ein Gedi.

(3) The probability of Essenes being agriculturalists given that Qumran was a commercial post is 0.7, $P(D \mid H_3)$.

Thus, I assigned:

H1: Qumran-Essene hypothesis $P(D \mid H_1) = 0.3$

H2: Qumran-Military hypothesis $P(D \mid H_2) = 0.7$

H3: Qumran-Commercial hypothesis $P(D \mid H_3) = 0.7$

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Philo	Agriculturalists	0.3	0.7	0.7

The strategy is to assign data probabilities to all the listed data in the previous section and to generate a single data probability for each hypothesis that will be used for a Bayes' theorem calculation. In this study, all the probabilities are my own. We now begin assigning data probabilities to the rest of category 1.

[Isolation] With regard to H_1, the probability of the Essenes being isolated given that Qumran was an Essene community is 0.6. With regard to H_2, the probability of the Essenes being isolated given that Qumran was a military post is 0.5. With regard to H_3, the probability of the Essenes being isolated given that Qumran was a commercial post is 0.5. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Pliny	Isolation	0.6	0.5	0.5

[Location of the Essenes according to "below"] With regard to H_1, the probability of Pliny meaning lower altitude by "below" thereby locating the Essenes in the vicinity of Ein Gedi, given that Qumran was an Essene community is 0. With regard to H_2, the probability of Pliny meaning lower altitude by "below" thereby locating Essenes in the vicinity of Ein Gedi, given that Qumran was a military post is 0.8. With regard to H_3, the probability of Pliny meaning lower altitude by "below" thereby locating the Essenes in the vicinity of Ein Gedi, given that Qumran was a commercial post is 0.8. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Pliny	"Below" means lower altitude: Essenes near Ein Gedi	0	0.8	0.8

With regard to H_1, the probability of Pliny meaning south by "below" thereby locating the Essenes at Qumran, given that Qumran was an Essene community is 1.0. With regard to H_2, the probability of Pliny meaning south by "below" thereby locating the Essenes at Qumran, given that Qumran was a military post is 0. With regard to H_3, the probability of Pliny meaning south by "below" thereby locating the Essenes at Qumran, given that Qumran was a commercial post is 0.

Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Pliny	"Below" means south: Essenes at Qumran	1.0	0	0

[The fate of Ein Gedi and Qumaran] With regard to H_1, the probability of Pliny knowing the fate of Qumran thereby not locating the Essenes at Qumran, given that Qumran was an Essene community is 0. With regard to H_2, the probability of Pliny knowing the fate of Qumran thereby not locating the Essenes at Qumran, given that Qumran was a military post is 0.6. With regard to H_3, the probability of Pliny knowing the fate of Qumran thereby not locating the Essenes at Qumran, given that Qumran was a commercial post is 0.6. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Pliny	He knew the fate of Qumran.	0	0.6	0.6

With regard to H_1, the probability of Pliny not knowing the fate of Qumran thereby making him unreliable, given that Qumran was an Essene community is 0.35. With regard to H_2, the probability of Pliny not knowing the fate of Qumran thereby making him unreliable, given that Qumran was a military post is 0.35. With respect to H_3, the probability of Pliny not knowing the fate of Qumran thereby making him unreliable, given that Qumran was a commercial post is 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Pliny	He did not know the fate of Qumran.	0.35	0.35	0.35

[No private property] With respect to H_1, the probability of Essenes possessing no private property, given that Qumran was an Essene community is 0.35. Similarly, H_2 and H_3 have probability 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	No private property	0.35	0.35	0.35

[Sabbath observant] With respect to H_1, the probability of Essenes being Sabbath observants, given that Qumran was an Essene community is 0.35. Similarly, H_2 and H_3 have probability 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Sabbath observant	0.35	0.35	0.35

[Opposed slavery] With respect to H_1, the probability of Essenes having been opposed to slavery, given that Qumran was an Essene community is 0.35. Similarly, H_2 and H_3 have probability 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Opposed slavery	0.35	0.35	0.35

[Celibate] With respect to H_1, the probability of Essenes having no wives, given that Qumran was an Essene community is 0.1. With respect to H_2, the probability of Essenes having no wives, given that Qumran was a military post is 0.7. With respect to H_3, the probability of Essenes having no wives, given that Qumran was a commercial post is 0.7. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Celibacy: no wives	0.1	0.7	0.7

With respect to H_1, the probability of Essenes having accepted marriage, given that Qumran was an Essene community is 0.7. Similarly, H_2 and H_3 have probability 0.7. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Celibacy: accepted marriage	0.7	0.7	0.7

[Rejected oath] With respect to H_1, the probability of Essenes having rejected oaths, given that Qumran was an Essene community is 0.35. Similarly, H_2 and H_3 have probability 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Rejected oath	0.35	0.35	0.35

[Politically indifferent] With respect to H_1, the probability of Essenes being politically indifferent, given that Qumran was an Essene community is 0.35. Similarly, H_2 and H_3 have probability 0.35. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Josephus	Politically indifferent	0.35	0.35	0.35

Then, category 1 probabilities are:

Category 1	$\Sigma P(D \mid H_1)$	$\Sigma P(D \mid H_2)$	$\Sigma P(D \mid H_3)$	Total Item
	4.8	6.1	6.1	13

We now turn to category 2 relating to the Dead Sea Scrolls:

[Who wrote the Dead Sea scrolls?] With regard to H_1, the probability of Essenes having written the scrolls, given that Qumran was an Essene community is 0.7. With regard to H_2, the probability of Essenes writing the scrolls, given that Qumran was a military community is 0.3. With regard to H_3, the probability of Essenes writing the scrolls, given that Qumran was a commercial post is 0.3. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The scrolls	The Essenes wrote them.	0.7	0.3	0.3

With regard to H_1, the probability of Sadduceans having written the scrolls, given that

Qumran was an Essene community is 0.3. With regard to H_2, the probability of Sadduceans having written the scrolls, given that Qumran was a military post is 0.3. With regard to H_3, the probability of Sadduceans having written the scrolls, given that Qumran was a commercial post is 0.3. Thus,

Source	Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The scrolls	The Sadduceans wrote them.	0.3	0.3	0.3

[Who hid the scrolls?] With regard to H_1, the probability of Essenes having written the scrolls and Qumranites hiding them, given that Qumran was an Essene community is 0.95. With regard to H_2, the probability of Essene having written the scrolls and Qumranites hiding them, given that Qumran was a military post is 0.1. With regard to H_3, the probability of Essenes having written the scrolls and Qumranites hiding them, given that Qumran was a commercial post is 0.25. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Essenes wrote and Qumranites hid them.	0.95	0.1	0.25

With regard to H_1, the probability of Sadduceans having written the scrolls and Qumranites hiding them, given that Qumran was an Essene community is 0. With regard to H_2, the probability of Sadducean having written the scrolls and Qumranites hiding them, given that Qumran was a military post is, 0.05. With regard to H_3, the probability of Sadduceans having written the scrolls and Qumranites hiding them, given that Qumran was a commercial post is 0.1. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Sadduceans wrote and Qumranites hid them.	0	0.05	0.1

With regard to H_1, the probability of Essenes having written the scrolls and non-Qumranites hiding them, given that Qumran was an Essene community is 0. With regard to H_2, the probability of Essenes having written the scrolls and non-Qumranites hiding them, given that Qumran was a military post is 0.6. With regard to H_3, the probability of Essenes having written the scrolls and non-Qumranites hiding them, given that Qumran was a commercial post is 0.6. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Essenes wrote and non-Qumranites hid them.	0	0.6	0.6

With respect to H_1, the probability of Sadduceans having written the scrolls and non-Qumranites hiding them, given that Qumran was an Essene community is 0.1. With respect to H_2, the probability of Sadduceans having written the scrolls and non-Qumranites hiding them, given that Qumran was a military post is 0.5. With respect to H_3, the probability of Sadduceans having written the scrolls and non-Qumranites hiding them, given that Qumran was a commercial post is 0.5. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Sadduceans wrote and non-Qumranites hid them.	0.1	0.5	0.5

Then, category 2 probabilities are:

Category 2	$\Sigma P(D \mid H_1)$	$\Sigma P(D \mid H_2)$	$\Sigma P(D \mid H_3)$	Total Item
	2.05	1.85	2.05	6

Finally, category 3 related to archaeological evidence is as follows:

[Pottery] With regard to H_1, the probability of Qumranites using their jars to hide the scrolls, given that Qumran was an Essene community is 0.9. With regard to H_2, the probability of Qumranites using their jars to hide the scrolls, given that Qumran was a military post is 0.15. With regard to H_3, the probability of Qumranites using their jars to hide the scrolls, given that Qumran was a commercial post is 0.2. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Qumranites used the jars to hide the scrolls.	0.9	0.15	0.2

With regard to H_1, the probability of non-Qumranites borrowing the Qumran pottery to hide the scrolls, given that Qumran was an Essene community is 0.05. With regard to H_2, the probability of non-Qumranites borrowing the Qumran pottery to hide the scrolls, given that Qumran was a military post is 0.7. With regard to H_3, the probability of non-Qumranites borrowing the Qumran pottery to hide the scrolls, given that Qumran was a commercial post is 0.7. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Non-Qumranites borrowed the jars.	0.05	0.7	0.7

With regard to H_1, the probability of Qumranites producing their own pottery and practicing deliberate isolation, given that Qumran was an Essene community is 0.4. With regard to H_2, the probability of Qumranites producing their own pottery and practicing deliberate isolation, given that Qumran was a military post is 0.3. With regard to H_3, the probability of Qumranites producing their own pottery and practicing deliberate isolation, given that Qumran was a commercial post is 0.3. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Qumranites practiced the deliberate isolation.	0.4	0.3	0.3

With regard to H_1, the probability of Qumranites simply making their own pottery for daily use, given that Qumran was an Essene community is 0.4. With regard to H_2, the probability of Qumranites simply making their own pottery for daily use, given that Qumran was a military community is 0.4. With regard to H_3, the probability of Qumranites simply making their own pottery for daily use, given that Qumran was a commercial post is 0.6. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
They simply made their own pottery.	0.4	0.4	0.6

[Locus 30] With respect to H_1, the probability of locus 30 being a *scriptorium* despite inkwells having no relation with the stuccoed furniture, given that Qumran was an Essene community is 0.1. With respect to H_2, the probability of locus 30 being *scriptorium* despite inkwells having no relation with the stuccoed furniture, given Qumran was a military post is 0.1. With respect to H_3, the probability of locus 30 being a *scriptorium* despite inkwells having no relation with the stuccoed furniture, given that Qumran was a commercial post is 0.1. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Locus 30 was *scriptorium*.	0.1	0.1	0.1

With regard to H_1, the probability of locus 30 being a dining room due to inkwells having no relation with the stuccoed furniture, given that Qumran was an Essene community is 0.2. With regard to H_2, the probability of locus 30 being a dining room due to inkwells having no relation with the stuccoed furniture, given that Qumran was a military post is 0.4. With respect to H_3, the probability of locus 30 being a dining room due to inkwells having no relation, given that Qumran was a commercial post is 0.5. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Locus 30 might be a dining room.	0.2	0.4	0.5

[Cave 8(3Q)] With regard to H_1, the probability of the manuscripts being from Qumran but the cupper scroll from somewhere else, given that Qumran was an Essene community is 0.3. With regard to H_2, the probability of the manuscripts being from Qumran but the copper scroll from somewhere else, given that Qumran was a military post is 0.3. With regard to H_3, the probability of the manuscripts being from Qumran but the copper scroll from somewhere else, given that Qumran was a commercial post is 0.3. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The manuscripts are from Qumran, but the copper scroll is not.	0.3	0.3	0.3

With regard to H_1, the probability of none of them originating from Qumran and 3Q being *genizah*, given that Qumran was an Essene community is 0.2. With regard to H_2, the probability of none originating from Qumran and 3Q being *genizah*, given that Qumran was a military post is 0.4. With respect to H_3, the probability of none originating from Qumran and 3Q being *genizah*, given that Qumran was a commercial post is 0.5. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
None originated from Qumran. The cave was *genizah*.	0.2	0.4	0.5

[Cemetery] With respect to H_1, the probability of secondary cemeteries existing and Qumran being celibate, given that Qumran was an Essene community is 0.2. With respect to H_2, the probability of secondary cemeteries existing and Qumran being celibate, given that Qumran was a military post is 0.2. With respect to H_3, the probability of secondary cemeteries existing and Qumran being celibate, given that Qumran was a commercial post is 0.2. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
Secondary cemeteries exist. Qumran was celibate.	0.2	0.2	0.2

With respect to H_1, the probability of secondary cemeteries not existing and a branch of married Essenes living at Qumran, given that Qumran was an Essene community is 0.85. With respect to H_2, the probability of secondary cemeteries not existing and married Essenes living at Qumran, given that Qumran was a military post is 0.1. With respect to H_3, the probability of secondary cemeteries not existing and married Essenes living at Qumran, given that Qumran was a commercial post is 0.1. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
A branch of married Essenes was at Qumran.	0.85	0.1	0.1

With respect to H_1, the probability of secondary cemeteries not existing and Essenes not living at Qumran, given that Qumran was an Essene community is 0. With respect to H_2, the probability of secondary cemeteries not existing and Essenes not living at Qumran, given that Qumran was a military post is 0.9. With respect to H_3, the probability of secondary cemeteries not existing and Essenes not living at Qumran, given that Qumran was a commercial post is 0.9. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The Essenes never lived at Qumran, which had nothing to do with celibacy.	0	0.9	0.9

With respect to H_1, the probability of excavated tombs being too few to reach conclusion, given that Qumran was an Essene community is 0.5. Similarly, H_2 and H_3 have probability 0.5. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The excavated tombs are too few to draw conclusion.	0.5	0.5	0.5

Then, category 3 probabilities are:

Category 3	$\Sigma P(D \mid H_1)$	$\Sigma P(D \mid H_2)$	$\Sigma P(D \mid H_3)$	Total Item
	4.1	4.45	4.9	12

Thus, data probabilities of the three categories are as follows:

	$\Sigma P(D \mid H_1)$	$\Sigma P(D \mid H_2)$	$\Sigma P(D \mid H_3)$	Total Item
Category 1	4.8	6.1	6.1	13
Category 2	2.05	1.85	2.05	6
Category 3	4.1	4.45	4.9	12
Total	10.95	12.4	13.05	31
$\Sigma P(D \mid H_k)/31$	**0.353**	**0.4**	**0.421**	

$\Sigma P(D \mid H_k)$ divided by 31 produces the final data probabilities for each hypothesis:

$P(D \mid H_1) = 0.353$

$P(D \mid H_2) = 0.4$

$P(D \mid H_3) = 0.421$

These will be used for calculation.

3.2.2. Weighted Data Probabilities

When we listed all the data and gave them data probabilities, we assumed that each datum carried equal significance for the final data probabilities. Obviously, we may think that one particular datum is more important than others or that a certain datum is useless. There are two ways to reflect such an impression upon the data probabilities. First, as we did in the above section, if we consider particular data to be trivial, we may simply assign equal probability to each hypothesis, thereby, preventing the particular data from making an impact upon the final data probabilities. Other legitimate data, then, will influence the final data probabilities.

Second, since we now have numerical figures, we may be able to manipulate them. For example, if we regard the datum "the Essenes wrote the scrolls" as significant, we may multiply the original data probability as follows: Originally, $P(D \mid H_1)$ is 0.7. Doubling the value produces the new value $P(D \mid H_1) = 1.4$. Originally, $P(D \mid H_2)$ is 0.3. Doubling it gives the new value $P(D \mid H_2) = 0.6$. Originally, $P(D \mid H_3) = 0.3$. The new value is $P(D \mid H_3) = 0.6$. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
The Essenes wrote the scrolls.	1.4	0.6	0.6

Similarly, if we consider the datum "a branch of married Essenes was at Qumran" to be important, we may double the data probabilities. Thus,

Data	$P(D \mid H_1)$	$P(D \mid H_2)$	$P(D \mid H_3)$
A branch of married Essenes was at Qumran.	1.7	0.2	0.2

The final data probabilities influenced by these are as follows:

$P(D \mid H_1) = 0.4$

$P(D \mid H_2) = 0.413$

$P(D \mid H_3) = 0.43$

This shows that H_1 added 0.05 to the final data probability. Although data manipulation offers much to explore, it would be better to adopt the simpler first option since we do not have a standard to regulate this kind of activity.

3.3 Prior Probabilities $P(H_k)$

Prior probabilities are subjective quantification of judgments regarding hypotheses. As the word "prior" implies, in practice we need to obtain them first before establishing data probabilities. Prior probabilities can be obtained easily: We simply express our initial opinion according to the probability calculus. For instance, if I initially think that the probability of Qumran being an Essene community is 0.4, the prior probability $P(H_1)$ is 0.4. If I think that the probability of Qumran being a military post is 0.2, the prior probability $P(H_2)$ is 0.2. Similarly, the prior probability of Qumran being a commercial post is $P(H_3) = 0.4$. Thus,

$P(H_1)$	$P(H_2)$	$P(H_3)$	Sum
0.4	0.2	0.4	1.0

Normally, each investigator determines prior probabilities and proceeds with data probabilities. In this paper, all probabilities are mine. The prior probabilities above will be used in calculation.

3.4 Bayes' Theorem Calculation

Since prior probabilities $P(H_k)$ and data probabilities $P(D \mid H_k)$ are established, we are ready to calculate posterior probabilities $P(H_k \mid D)$ with Bayes' theorem. The theorem is:

$$P(H_k \mid D) = \frac{P(D \mid H_k)P(H_k)}{\sum P(D \mid H_i)P(H_i)}$$

Hypotheses:

H_1: Qumran-Essene Hypothesis

H_2: Qumran-Military Post Hypothesis

H_3: Qumran-Commercial Post Hypothesis

Prior Probabilities:

$P(H_1) = 0.4$

$P(H_2) = 0.2$

$P(H_3) = 0.4$

Data Probabilities:

$P(D \mid H_1) = 0.353$

$P(D \mid H_2) = 0.4$

$P(D \mid H_3) = 0.421$

Using the table, calculation results in:

Hypothesis H	Prior Probabilities $P(H_k)$	Data Probabilities $P(D \mid H_k)$	Product $P(D \mid H_k)P(H_k)$	Posterior Probabilities $P(H_k \mid D)$
1	0.4	0.353	0.1412	**0.363**
2	0.2	0.4	0.08	**0.205**
3	0.4	0.421	0.1684	**0.432**
	Sum 1.00		Sum 0.3896 = P(D)	Sum 1.00

Thus, posterior probabilities are:

$P(H_1 \mid D) = 0.363$

$P(H_2 \mid D) = 0.205$

$P(H_3 \mid D) = 0.432$

This means that we have a 36% probability that Qumran was an Essene community; 21% probability that Qumran was a military post; and 43% probability that Qumran was a commercial post.

4. Conclusion

In conclusion, we have presented the procedure to solve the Qumran problem. It contained four steps. (1) We have established and listed available data related to the Qumran function hypotheses. We divided the data into three categories: ①written records of ancient writers, ②the Dead Sea scrolls, and ③the results of the excavation.

Category① listed the characteristics of the Essenes described by Philo, Pliny, and Josephus. The Essenes were agriculturalists, isolated, located either in the vicinity of Ein Gedi or at Qumran depending on the meaning of the word "below," without private property, Sabbath observant, against

slavery, celibate, no-oath-taker, and politically indifferent.

Category② listed two main questions: who wrote the Dead Sea scrolls? and who hid them? There are two possibilities regarding the first question: Essenes wrote the scrolls or Sadduceans wrote them. The second question is divided into two: Qumranites hid the scrolls or non-Qumranites hid them.

Category③ listed archaeological evidence related to pottery, locus 30, cave 8(3Q), and the cemetery. The pottery of the caves is identical to that of the settlement, which had a potter's workshop. Undecorated plain assemblages at Qumran are distinct from other Judean sites. In locus 30, there are no relations between inkwells and the stuccoed furniture. In cave 8(3Q), the coppe scroll and 14 manuscripts, which were away from it, were found. The cave is 2 km away from the settlement. The cemetery had prongs which have been interpreted as secondary cemeteries. The question of celibate Essenes is determined by how we interpret the presence of women's graves at the "secondary" cemeteries.

(2) We have numerically assessed the data to establish data probabilities $P(D \mid H_k)$. The probability of data given the hypothesis H_1: Qumran was an Essene settlement is $P(D \mid H_1) = 0.353$. The probability of data given the hypothesis H_2: Qumran was a military post is $P(D \mid H_2) = 0.4$. The probability of data given the hypothesis H_3: Qumuran was a commercial post is $P(D \mid H_3) = 0.421$.

(3) We have established prior probabilities $P(H_k)$. The prior probability of H_1 is $P(H_1) = 0.4$. The prior probability of H_2 is $P(H_2) = 0.2$. The prior probability of H_3 is $P(H_3) = 0.4$.

(4) We have calculated posterior probabilities $P(H_k \mid D)$ with Bayes' theorem. The calculations gave: the probability of H_1 given the data is $P(H_1 \mid D) = 0.363$; the probability of H_2 given the data is $P(H_2 \mid D)$ is 0.205; and the probability of H_3 given the data is $P(H_3 \mid D) = 0.432$. This means that we have a 36% probability that Qumran was an Essene community; 21% probability that Qumran was a military post; and 43% probability that Qumran was a commercial post.

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