

## TESTING COMPETING ARCHAEOLOGICAL THEORIES OF ISRAEL'S ORIGINS USING COMPUTATION TECHNIQUES

### 1. INTRODUCTION

The biblical account about the Exodus has been challenged:

«The conclusion – that the Exodus did not happen at the time and in the manner described by the Bible – seems irrefutable when we examine the evidence at specific sites where the children of Israel were said to have camped for extended periods during their wandering in the desert (numbers 33) and where archaeological indication – if present – would almost certainly be found» (FINKELSTEIN, SILBERMAN 2002, 63).

This categorical denial of the event has also been challenged:

«On the other hand, what might one expect to find as artifacts of Israelites camped in the desert for forty years more than three thousand years ago? If they were wandering, as opposed to living in permanent structures, they would probably have used tents with postholes, just as the Bedouin of today do. Consequently, an archaeologist searching for visible remnants of the Exodus is probably not going to find the remains of permanent structures, and any tent peg holes would long since have been obliterated» (CLINE 2015, 93).

This disagreement belongs to a larger dispute about what lack of evidence means and reasonably bio-mathematical models are not of use in its resolution because they evaluate evidence and not lack of evidence. This investigation not only introduces new tools of analyzing evidence, but also it examines evidence that so far has been overlooked: the orientation of the borders between material cultures. Consequently the scope of the investigation is not to prove or disprove the Exodus, but to test the many conflicting theories concerning the origins of Israel, regardless of the historicity of the Exodus. All these theories can be grouped into four categories each presenting different explanations about the Iron Age I appearance of highland settlements in Israel.

The four categories are:

(a) The settled Canaanite theories advocate that Israel split out of sedentary Canaanites, and socio-cultural distinctions appeared and grew after the split (e.g. DEVER 2006, 125).

(b) The theories of nomadic Canaanites were developed by Finkelstein. They argue that the Central Hill was settled by nomadic tribes who lived on the Central Hill and «returned to sedentary life at the end of the Late Bronze

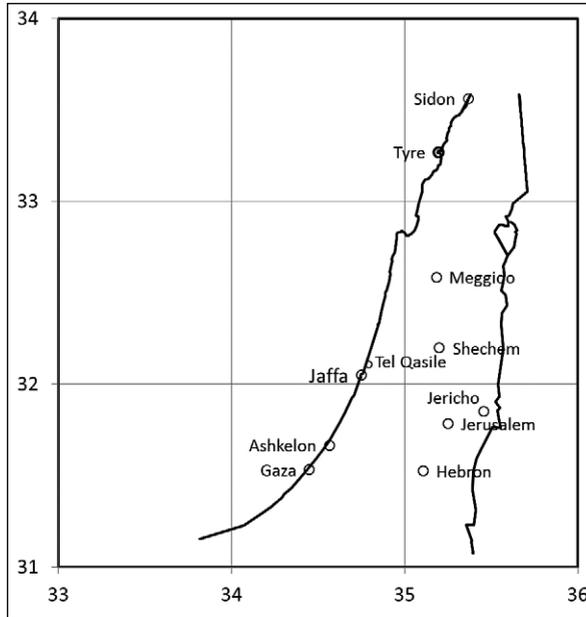


Fig. 1 – The Land of Canaan.

Age due to the dissolution of the Canaanite city-state system...» (see pastoral Canaanite theory of Finkelstein in KILLEBREW 2005, 183).

(c) The theories of immigration of nomadic tribes argue that the Central Hill was settled by nomadic tribes coming from outside the territory of Canaan (Fig. 1). Some clues suggest an origin from Haran, Northern Syria (KNOHL 2008, 63), other clues point to Egypt (KNOHL 2008, 66), or to the Shasu nomads of Sinai (LEVY, HOLL 2002, 113; LEVY *et al.* 2004, 67; FINKELSTEIN *et al.* 2007, 171; RAINEY 2007, 47; SPARKS 2007, 473; FAUST 2008, 184; 2015; RÖMER 2015, 311).

(d) The multiple origin theories combine all of the above (e.g. NAAMAN 2015).

Naturally, the competing theories have been debated and examined time and again (BIMSON 1989; KILLEBREW 2005, 183; FAUST 2008, 170-187) yet no consensus emerged. This attempt will use tools borrowed from physics and bio-mathematics to test the feasibility of each category listed above.

The application of exact sciences for interpretation of archaeological evidence is not new and the returning readers of «Archeologia e Calcolatori» need no validation for it. However for the audience of other research sectors there is plenty of literature with examples and justification (e.g. BOYD, RICHESON 1987; HENRICH 2004; POWELL *et al.* 2009; BARCELÓ *et al.* 2010;

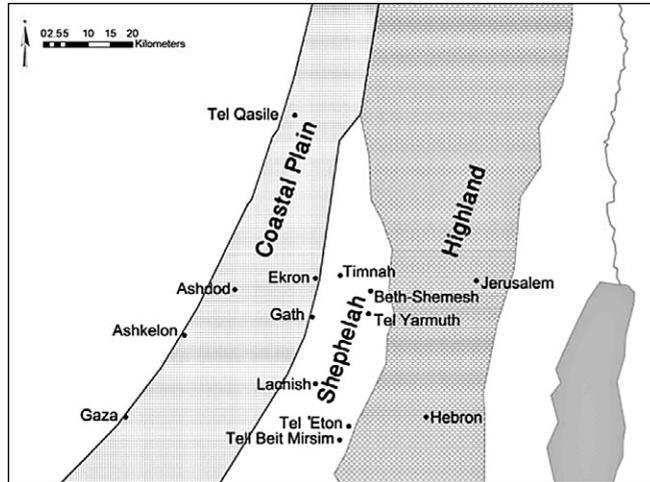


Fig. 2 – Three cultures and two borderlines in Canaan of Iron Age I – Reproduced from FAUST, KATZ 2011, with the kind permission of Avraham Faust.

FOGARTY *et al.* 2015). The innovation of this article consists of matching adequate techniques for testing the above theories.

## 2. CONFLICTING ARCHAEOLOGICAL EVIDENCE

On one hand many cultural traits are shared by both Canaan (Lowland) and Israel (Highland), while on the other hand the evidence indicates important socio-cultural distinctions:

– Shared traits: the cultural traits shared by Canaan and Israel comprise language, writing, and mythology (the very name of Israel is related to the Canaanite god El). They even shared units of measure for example: the cubit and the shekel (NAAMAN 2005, 218, 219).

– Distinct traits: the archaeological evidence indicates sharp discontinuities of other traits (KILLEBREW 2005, 99, 169, 199; STAGER 1995, 348, principally in reference to Philistine territory). An archaeological investigation (FAUST, KATZ 2011) traced two sharp border lines in an area less than 100 km wide. The narrow territory lying between the Mediterranean and the Jordan River housed three cultures (Fig. 2). Table 1 describes the cultural traits showing clear discontinuities along the lines of Fig. 2.

– Cultural boundaries: this work refers to cultural boundaries in terms of demarcations between material cultures. «The question of the equivalence of archaeological cultures and past peoples was raised within the framework of

Discontinuity	Between	Comments
Religion	Canaan-Israel	No temples, almost no idolatry in Israel (FINKELSTEIN, SILBERMAN 2002)
Ideology	Canaan-Israel and Philistine-Israel	Egalitarian corporate rule (FAUST 2008) a.k.a. covenantal society (ELAZAR 1998a) in Israel as opposed to oligarchic rule of Canaanite city-states (SMITH 2008), and of Philistine Pentapolis (GOLDEN 2004, 160)
Housing	Canaan-Israel and Philistine-Israel	Four room house in Israel (Fig. 3)
Tombs	Canaan-Israel	No tombs found in Israel
Pottery	Canaan-Israel and Philistine-Israel	Simple design and no imported pottery in Israel. Bi-chrome pottery in Philistia; rare or nonexistent in either Israel or Canaan
Pork consumption	Philistine-Israel and Philistine Canaan	Large pork consumption in Philistia.
Pork consumption	Canaan-Israel	No pork in Israel; reduced pork consumption in Canaan

Tab. 1 – Cultural discontinuities in Southern Canaan of Iron Age I.

culture-history» (JONES 1997, 106). Debating the question of identifying the Iron Age I material culture with Israel is out of scope. Since «the existence of ethnic groups as bounded socio-cultural entities is still accepted» (JONES 1997, 110) this work shall follow archaeologists and refer to the Iron I distinct material culture of the settlements on the highlands of ancient Israel as Proto-Israel (DEVER 2002, 118).

Boundaries between cultural traits are not unprecedented. For example JIREČEK (1911) detected a line of discontinuity in the Balkan Peninsula dividing the Byzantine Empire into two language cultures: Greek and Latin. Currently, a similar cultural divide can be spotted in the same region: in Croatia, alcohol use among students is 16% above European average, while in neighbouring Bosnia it is 17% below European average (HIBELL *et al.* 2012). Moreover, detected boundaries divide not only cultural traits, but also material cultures; for example the Dniester river separated in the Neolithic between the Criș material culture and the Dniester-Bug material culture (ANTHONY 2010, 149-150).

The theories of category (a) and (b) require explanations of the distinct traits. The theories of category (c) need to reconcile the question of shared traits and of continuity from the Bronze Age. This work shall put all the theories to test.

### 3. TESTING THEORIES OF CATEGORY (A)

Scholars observed (e.g. FINKELSTEIN *et al.* 2007; HAWKINS 2007, 70; STAGER 2003, 69) that the distinct traits of Proto-Israel (Table 1) are related to an egalitarian way of life<sup>1</sup>. Theories of category (a) tend to state that the

<sup>1</sup> Pork consumption does not appear to be related to an egalitarian principle; nevertheless pig avoidance in some ancient societies was class related (HECKER 1982; LOBBAN 1994; SAPIR-HEN *et al.* 2013).

Name	Location	Reference
Puritans	America	(SLETCHER 2004)
obște	Romania	(BĂDESCU <i>et al.</i> 2005, 539; LIVNI 2016)

Tab. 2 – Covenantal faiths that did generate ethnic groups.

Name	Sect Location	Reference
Early Christians	Roman Empire	«ethnic mixture» (LAMPE, JOHNSON 2003, 102); some debate that they «defined themselves using ethnic reasoning» (BUELL 2001, 4)
Puritans	England	PEDERSON 2014, 118
The Vaudois	France	SANTINI 1974, 39

Tab. 3 – Covenantal faiths that did not generate ethnic groups.

split was of an anti-establishment nature which opposed inequality (see for example theories of Medenhall and Gottwald in BIMSON 1989).

A new egalitarian ideology did in some cases catalyze ethno-genesis (see examples of Table 2). However the American Puritan experience (Table 2) involved immigration (BREMER 1995, 36, 44), i.e. they rather belong to theories of category (c). Similarly, the evacuation of the Roman Administration initiated the Romanian covenantal *obște* (LIVNI 2016), which reasonably also makes it category (c).

All the examples of Table 3 with no clear-cut ethnic founding are religious break-ups matching category (a); by conjecture category (a) should involve no ethno-genesis. Even if Canaan were an exception and the new ideology did generate ethnic distinctions, it is not clear why it also entailed geographic split-up since «ethnic groups are not merely or necessarily based on the occupation of exclusive territories» (BARTH 1998, 15).

Nevertheless for the sake of testing, let us assume that the revolutionary ideology did generate both a new ethnic group and geographic separation; subsequently let us test if the expected boundary is consistent with Fig. 2. I'll start with two observations:

a) As any innovation, the new egalitarian faith has three possible fates (MOLLEMAN *et al.* 2013):

1. Fixation: the innovation is accepted by all;
2. Extinction: the innovation is rejected by everybody;
3. Polymorphism (CAVALLI-SFORZA, FELDMAN 1981, 44). Some accept it some reject it.

b) The propagation of a cultural trait involves two mechanisms: migration and contagion (GATHERER 2002).



Fig. 3 – Typical highland four room house; the layout reflects the egalitarian ethos of the settlers (FAUST 2008, 78, 79); this house is exhibited at Tel Hazor, Israel.

### 3.1 Migration

Theories of category (a) exclude *population migration*; nevertheless, there is always an exchange of population between neighboring towns; this is sometimes called *random migration* (e.g. YANEV, YANEV 1995). Most of random migration occurs for reasons of marriage and business.

As carriers of a foreign trait move into a site the trait proliferates. This type of cultural propagation is known as *diffusion*. The literature (CRANK 1975, 2-4) rigorously derives the equation of diffusion:

$$\dot{p}(x,t) = M \left[ \frac{\partial^2 p(x,t)}{\partial x^2} \right] \quad (1)$$

Equation (1) is also known as Fick's law of diffusion (MACDONALD 1977, 47).

#### 3.1.1 Test 1 – Diffusion

This test demonstrates that random migration alone doesn't produce traceable boundaries between material cultures.

The application of (1) to cultural traits is not new (e.g. CAVALLI-SFORZA, FELDMAN 1981, 40). In (1)  $p(x, t)$  symbolizes the popularity of the trait at point  $x$  and time  $t$ . The justification of the applicability of the equation for spread of genetic traits has been proposed by FISHER (1937); it is related to the assumption that genes propagate by the exchange of population between neighboring towns; this is sometimes called *random migration* (e.g. YANEV,

Trait	Continuity	Reference
Four room house	11 <sup>th</sup> -6 <sup>th</sup> century BCE	BUNIMOVITZ, FAUST 2003; SHILOH 1970
No burial sites	Iron Age I	KLETTER 2002
Poor pottery repertoire	Iron Age I	FAUST 2008, 66-69

Tab. 4 – Continuous cultural traits in the Highland.

YANEV 1995). Since the random migrants carry both genetic and cultural traits the extension of equation (1) to cultural traits is straightforward.

Given that we are talking about an exchange of population, the average distance of all the migrants is zero. However, the variance of the distances of all the migrants is positive and it is a proper comparison between populations with low and high level of random migration. This variance is the  $M$  [ $\text{km}^2/\text{year}$ ] of equation (1) (CAVALLI-SFORZA, FELDMAN 1981, 41).

The archaeological evidence shows continuity of cultural traits in Proto-Israel, within specified time intervals (Table 4). In mathematical terms this indicates that within those time intervals either equilibrium or quasi-equilibrium was achieved.

Equilibrium implies that  $\dot{p} = 0$ . Consequently, in virtue of (1)  $\frac{\partial^2 p}{\partial x^2} = 0$ . Diffusion (or random migration) adequately explains the propagation of a trait if the archaeological evidence indicates either a gradual or no increase of the trait. This condition is violated across border points (Table 4). In other words diffusion alone cannot explain borders between material cultures.

### 3.2 Random migration + contagion

A novelty may also spread by parental and school education, peer pressure, trade, revolt instigation, missionary work, imitation of role models, etc. As in other investigations (GATHERER 2002) in the present study, this type of trait propagation is called contagion. CAVALLI-SFORZA, FELDMAN (1981, 42) recommend using the “logistic” term for the contagion term  $\alpha p(1-p)$  and then (1) becomes (2).

$$\dot{p} = M \left( \frac{\partial^2 p}{\partial x^2} \right) + \alpha p(1-p) \quad (2)$$

First, I shall intuitively justify the logistic term. When  $p$  is zero then no contagion occurs because there are no carriers of the trait. When  $p$  is one, then there is no one to convert. The simplest expression that cancels out for  $p$  being either zero or one is:  $\alpha p(1-p)$ .

In order to substantiate the applicability of the logistic term, I recycled here its derivation based on the derivation of a similar term by CAVALLI-SFORZA and FELDMAN (1981, 131).

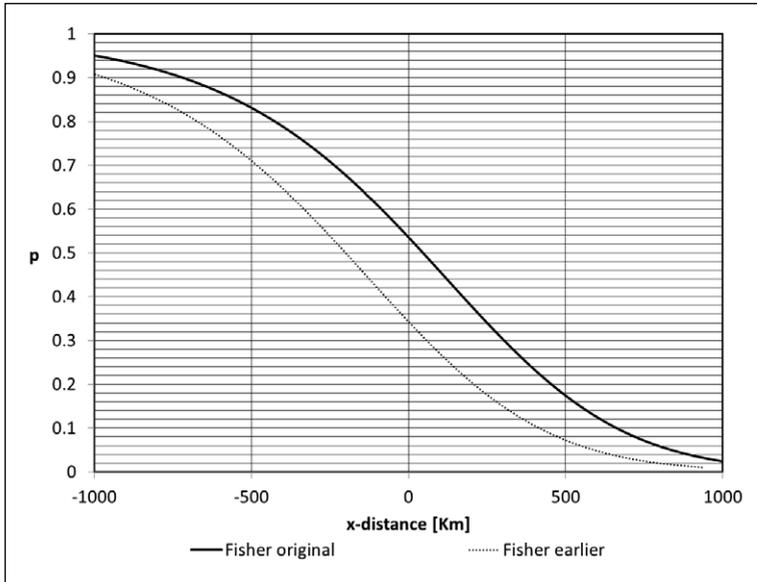


Fig. 4 – Fisher’s travelling wave; the bold line has been numerically calculated by Fisher; the dotted line shows the popularity  $p$  of the trait one generation earlier; coefficients  $M = 6400 \text{ km}^2/\text{generation}$  and  $\alpha = .26/\text{generation}$ ; as the waves travels  $p$  increases everywhere and ultimately the advantageous curves is fixated.

A *master* has a skill that an *apprentice* does not possess. The population consists of  $n$  people of which  $np$  are *masters* and  $(1 - p)n$  are *apprentices*. The chance that a master-apprentice encounter produces a new master is  $\rho$  ( $\rho \ll 1$ ).

A *master* can meet an expected number of  $k$  people in a unit of time.  $np$  *masters* will have  $npk$  contacts per unit of time. However, only  $npk(1 - p)$  contacts will be with apprentices. The chance of all of them ending in failure is:  $(1 - \rho)^{npk(1-p)}$ .

The chance of success is:  $1 - (1 - \rho)^{npk(1-p)}$ . If  $\rho$  is small then the chance of success is  $npk(1 - p)$ . Each success increases by  $p$  by  $\frac{1}{n}$ . Thus the increment of  $p$  in a unit of time is  $\dot{p} = pkp(1 - p)$ . Substituting  $\alpha = \frac{1}{n} k\rho$  one obtains:

$$\dot{p} = \alpha p(1 - p) \tag{3}$$

FISHER (1937) showed that the solution of (2) is a travelling wave time history (Fig. 4). A Fisher wave is not consistent with cultural boundaries because it ends up in fixation (Fig. 4). Borders imply that the traits spread carried by a Fisher wave across many kilometers and then stop. Theoretically

speaking, a Fisher wave stops if there is either no random migration,  $M = 0$  or no contagion  $\alpha = 0$  since the velocity of the wave is  $\sqrt{M\alpha}$  (FISHER 1937).

Reasonably, random migration always takes place; consequently, only absence of contagion is a practical explanation of a stopped wave. In our case, lack of contagion in a region where  $x > D$  ( $D$  for distance from an origin) is reasonable; it means that an Israelite migrant into the Lowland could not convince a Canaanite to renounce idolatry, to abstain from fancy pottery, or to change his burial customs. Thus the proper way to test theories of category (a) is by assuming a Fisher wave travelling from an origin until it reaches the distance  $x = D$ . Here it stops because  $\alpha$  vanishes.

### 3.2.1 Test 2 – Migration and Contagion – explain border

This test proves that:

- i. random migration combined with contagion can produce traceable borders between two material cultures;
- ii. the boundary is a result of a split of an original population into two distinct populations;
- iii. in the particular case when the territory of the original population is long and narrow, the boundary will be parallel to the narrow dimension.

Theories of category (a) claim that Israel split from the rest of Canaan as a result of a new ideology. This new ideology started somewhere in the territory that became Israel and spread like a Fisher wave of (2). I simulated a Fisher wave starting in Jericho; I stopped the wave when it reached Tel Qassile (modern Tel Aviv). In other words when  $x$  exceeds the distance between Jericho to Tel Qassile (about 100 km) the appeal of the new ideology vanishes or  $\alpha(x > 100) = 0$ . The simulation did arrive at a border line (Fig. 5); consequently, the theories of category (a) can produce a geographic split between two cultures of a population. However the line predicted by the simulation is not consistent with the archaeological evidence (Fig. 2). The lines of Fig. 2 go from N to S while the simulation Fig. 5 predicts an EW orientation of the border. Either stopping at another distance or starting elsewhere (e.g. Sidon and Gaza) consistently created EW borders. The rationale for the EW line is that traits are more uniform along the narrow dimension than along the longer dimension<sup>2</sup>; an ideology spreading from Jericho reaches Tel Qasile before Megiddo (Fig. 1).

One should note that Fig. 2 focuses on Judah, consequently test 2 rules out category (a) for the portion of Proto-Israel that later became Judah.

<sup>2</sup> Other examples of cultural borders across the narrow dimension: Italy and England (GONZÁLEZ 2010), Norway (NIEMI 2007), The Roman Empire (GIBBON 1847), and the pre-civil war USA (EATON, KIRWAN 2015).

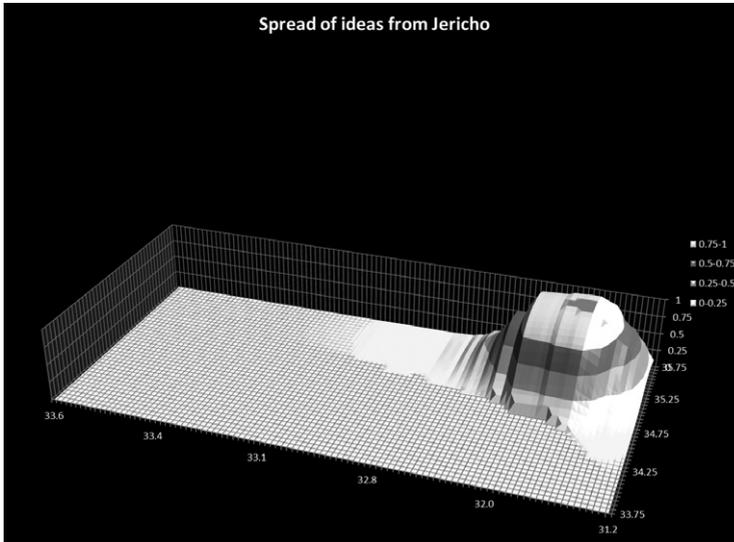


Fig. 5 – Spread of innovation from Jericho. The height on the chart at every location on the map represents the abundance of the spreading trait. The propagation stops when one observes a borderline between two distinct areas: one with a material culture rich in the followed trait and another one in which the trait is practically nonexistent; the border is along the parallel of latitude 32.1<sup>0</sup>, which crosses Tel Qassile (Tel Aviv) – Afeq (Rosh HaAyin) – Shiloh.

However in the Northern Central Hill, which later belonged to the Kingdom of Israel the borders between the Proto-Israelite settlements and the Lowland Canaan follow the same pattern and by analogy test 2 rules out category (a) for the entire Proto-Israel.

*Summary of tests of theories of category (a)* – The NS borders of Fig. 2 are inconsistent with theories of category (a).

#### 4. TESTING THEORIES OF CATEGORY (B)

##### 4.1 *Continuity of traits*

These theories explain borders as a demarcation between two types of «ecological-human zones: the fertile lowland and the frontier» (FINKELSTEIN 1990, 682). Although these theories need not explain continuities, scholars note that continuities do not validate category (b): «Elements of continuity from the Late Bronze culture do not necessarily indicate that the inhabitants came from the framework of Canaanite settled society» (FINKELSTEIN 1990); «... the Canaanite components in the material culture of the settlers should not be taken as proof of their origin in Canaanite society» (MAZAR 1990).

Hence, the grounds for this category consist of archaeological evidence of some sort of nomadic existence prior to Proto-Israel: «Isolated cultic places and cemeteries, not related to any sedentary sites indicate that the highlands of Canaan were not depopulated... This evidence, which hints at a large non-sedentary population in the frontier regions of Canaan...» (FINKELSTEIN 1990, 684).

The study of boundaries between cultures involves the question of «what social process and what kinds of social groups can we discern by studying discontinuities in the archaeological record» (STARK 1998, 8). The information of Table 1 and the hypothesis of category (b) implies a process of settlement of highland pastoralists, who incrementally adopt egalitarian burial habits, stop building cultic places, acquire a poor repertoire of pottery, avoid pork consumption and build four room houses.

#### 4.2 *Conflict between sedentary and egalitarian lifestyle*

«The crystallization of the Israelite identity must have been a long historical process» (MAZAR 1990). I don't propose to test this affirmation, because I see no reason to question it. However, I propose to test the theory of a process whereby a nomadic pastoralist population settles down gradually abandoning a stratified structure evidenced by «cultic places and cemeteries». The reason for questioning this scenario is because it involves an unexpected turn from stratification to egalitarian lifestyle. Typically, sedentary pre-state societies opt for inequality (UPHAM 1990, 16; WASON 2004, 63), while nomadic life is consistent with an egalitarian ethos (see Schneider's principle in BOEHM 2001, 103, 104).

#### 4.3 *Justice administration*

Sedentary societies opt for stratification mostly because it offers means of settling disputes about land and surplus. Studies of other sedentary egalitarian societies show that many grew from hunter-gatherers or horticulturalists; they settled disputes by arbitration, for example the Mohawks (DICKSON-GILMORE 1996, 100-101; O'BRIEN 1993, 32), Celts of Eastern Languedoc of Iron Age (LULEY 2016) the Bwa of Bourkina Faso (DUEPPEN 2008, 258) and the Kapauku of Melanesia (SILLITOE 1998, 159). The mediation is respected due to the prestige of the arbitrator and it required neither distinction between right and wrong (SILLITOE 1998, 159) nor a «consequential allocation of guilt» (DICKSON-GILMORE 1996, 101).

Theories of category (b) assume a transfer from stratified to egalitarian lifestyle. Stratified societies have rulers decreeing norms of behaviour. Law scholars refer to this arrangement as a *normative legal system* (WALDRON *et al.* 2009, 5). It is reasonable that an egalitarian Proto-Israel with stratified roots embraced a normative justice system with an egalitarian adaptation.

Later descendants of Proto-Israel did have had a normative concept known as the *covenant*. They shared a view that everyone is an equal signatory to the covenant; reasonably, the covenantal concept had its roots in the egalitarian ethos of Proto-Israel. LIVNI and STONE (2015) numerically studies the justice administration of a society regulated by a covenant however with no ranks, no police or other dedicated law enforcement; the justice administration of their mathematical model consists of a covenantal faith, a periodical assembly applying peer pressure on transgressors to become righteous and a cohesion factor keeping the righteous on their virtuous path.

LIVNI and STONE (2015) concluded that the covenantal justice administration requires the simultaneous presence of an effective Sabbath assembly and a strong cohesion factor. Their model is based on the analogy between the spread of infectious diseases and the spread of criminality. This analogy has several precedents (e.g. FEICHTINGER *et al.* 1996; EPSTEIN 1997; ROSSI 2002; ZHAO *et al.* 2002; NUÑO *et al.* 2008). A gradual build-up of both elements implies that at the beginning both of them were weak or missing. In numerical terms, the strength of the Sabbath is measured by the factor  $\psi_0 = \frac{\gamma}{\beta}$ , where  $\gamma$  represents the probability of repentance due to the peer pressure of the assembly and  $\beta$  represents the probability of corrupting a susceptible congregant by a transgressor (LIVNI, STONE 2015). The upper bound of  $\gamma$  is  $\gamma < 1/\tau$ , where  $\tau$  symbolizes the time interval between assemblies (LIVNI, STONE 2015). The same study estimated a reasonable value of  $\beta = 1.5/\text{week}$  by analogy to the value of  $\beta$  in published drug addiction studies (MACKINTOSH, STEWART 1979). Thus the upper bound of  $\psi_0$  is obtained by  $\psi_0 = \frac{\gamma}{\beta} < \frac{1}{\beta\tau} < \frac{1}{1 \times 1.5} < 0.667$ . The cohesion factor weakens as a result of intermingling with other cultures and hence the benefit of dietary rules (see more in ROSENBLUM 2010); poverty also weakens the cohesion factor.

#### 4.3.1 Test 3 – Examining justice administration assuming category (b)

This test rules out theories of category (b); the test shows that a gradual evolution from a ranked to unranked covenantal society is not feasible in sedentary societies, while category (b) intrinsically implies such a gradual transition.

Let us assume a theory of category (b). Reasonably, the cohesion factor grew from 0 to a healthy level, as fast as measures of disconnection from other cultures and of combatting poverty gained strength. I compared two cases using the model of LIVNI and STONE (2015): one with a robust cohesion factor and one with a weak one (Fig. 6). The results show that a cohesion factor close to 6/week assures the survival of the community even with a reasonably lower than maximum Sabbath Number of  $\psi_0 = .4 < 0.667$ . However at the time of the hypothetical return to sedentary lifestyle the cohesion factor had to be close to 0. A simulation with a  $\psi_0 = .4$  and a cohesion factor of .2333/week

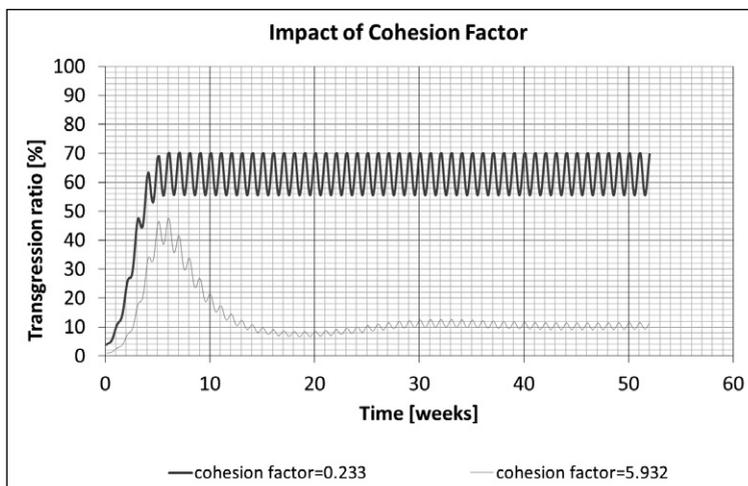


Fig. 6 – The cohesion factor becomes more important as the beneficial influence of the Sabbath assembly declines; the chart shows that when the Basic Sabbath Number  $\varpi_0=4$  a robust cohesion factor still keeps transgression below 10%; however as the cohesion factor vanishes the transgression ratio rapidly climbs to significant percentages; for example the chart shows how a low cohesion factor brings the majority of the population to transgression as a matter of six weeks.

shows that the majority become transgressors in a matter of weeks (Fig. 6). The test results are inconsistent with the theory of category (b) because the simulation of the mathematical model contradicts the feasibility of a gradual buildup of a covenantal society.

## 5. TESTING THEORIES OF CATEGORY (C)

### 5.1 Judah

5.1.1 Test 4 – This test shows that theories of category (b) and (c) are compatible with the borders of Fig. 2

The explanation of the borders (Fig. 2) for theories of category (b) and (c) is straightforward. The cultural traits were carried by the immigrants. Proto-Israel became a «...sedentary population living in small communities of farmers and herders without a central political authority though probably with major cultic centers ...» (FINKELSTEIN *et al.* 2007, 70).

The boundaries of their egalitarian culture were constrained by others' resistance to their penetration and by their opposition to inequality. This is consistent with MCGUIRE (1982) who argues that the key factor in ethnic divisions is differential power distribution.

5.1.2 Test 5 – This test examines whether theories of category (c) are compatible with continuities of Table1

One of the strongest arguments in favor of category (a) consists of the shared cultural traits of section 2 (e.g. DEVER 2006, 125). The previous paragraph argued that the compatibility of category (c) with the borders of Fig. 2 is trivial; however category (c) needs to explain the shared cultural traits of section 2. Advantageous traits spread by diffusion and contagion. I already mentioned earlier that this question has been addressed by Finkelstein and Mazar. Nevertheless, two simulations, one assuming the spread of a contagious innovation from the N<sup>3</sup> and another simulating the spread of the alphabet from the S (GOLDWASSER 2006)<sup>4</sup> further visualise how continuity is not evidence against category (c) theories.

5.2 Philistia

By consensus, the Philistines also settled by population migration (KIL-LEBREW 2013, 17). Surprisingly, the Eastern boundary of the Philistine area (Fig. 2) coincides with ... Internet Age Cross-Israel Highway, a.k.a. Highway 6. In a private communication, Faust explained the coincidence by the fact that both Highway 6 and the ancient *Coastal Road* a.k.a *Via Maris* followed topographic constraints. As a result, one should not be surprised that they coincide. This indicates that the source of the Philistine ethnocentricity is competition over control of the road in line with MCGUIRE 1982. In order to maximize their revenues the Philistine interest coincided with keeping foreigners out.

At  $t = 0$  a migrant crosses the border and at a border town; his ceramic preference in his town is out of favour. He is the only person advocating the cultural trait. The popularity of his ceramic is  $t = 0 = 1/N$ , where  $N$  represents the population of the town. Nevertheless the tiny  $p(0) > 0$  disturbs the previous equilibrium  $p=0$ , and produces a negative  $\dot{p}$  so that Fisher's equation (FISHER 1937) is applicable except  $\alpha$  is negative:

$$\dot{p} = M \left( \frac{\partial^2 p}{\partial x^2} \right) - \alpha p(1 - p) \tag{4}$$

In (4)  $\alpha$  is the coefficient of the logistic component. At this point in time one can approximate  $(1 - p) \sim 1$ . Since  $\dot{p} < 0$  the expression  $(1 - p) \sim 1$  remains valid through the transient of  $p(t)$  to equilibrium. Therefore at steady state, equation (4) can be approximated to:

<sup>3</sup> <https://drive.google.com/file/d/0ByXoJk5buPIMMXNMWDNxcIVjUnc/view>.

<sup>4</sup> <https://drive.google.com/file/d/0ByXoJk5buPIMN3pBQWVONkE4Q1E/view>.

Town	Distance from border of Judah [km]	Bi-chrome pottery (Philistine)		Collared-rim jar (Israelite)	
		Map 19.4	(6)	Map 19-2	(6)
Izbet Sarta	+1.	yes	yes	yes	yes
Afeq	0.	yes	yes	yes	yes
Ekron	-10	yes	yes	no	no
Beth Shemesh	0	yes	yes	yes	yes
Gath	-10	yes	yes	no	no
Ashdod	-35	yes	yes	no	no
Beth El	+25	yes	no	yes	yes
Shiloh	+35	no	no	yes	yes
Gezer	-5	yes	yes	no	no
Tel-en Nasbeh	20	yes	no	yes	yes
Tel Beit-Mirsim	0	yes	yes	yes	yes

Tab. 5 – Consistency between predictions of (6) and actual archaeological evidence.

$$M \left( \frac{\partial^2 p}{\partial x^2} \right) - \alpha p = 0 \quad (5)$$

The expected opposition to a Philistine trait (e.g. bi-chrome pottery) will show in the material culture the well-known solution to the differential equation (5):

$$p(x) = p_0 e^{-x \sqrt{\frac{\alpha}{M}}} \quad (6)$$

In (6),  $x$  symbolizes the distance from the border,  $M$  is proportional to the area of random migration per generation and  $\alpha$  expresses how strong the resistance to the trait is. Fig. 7 plots values of  $p$  as a function of  $x$  for reasonable values of  $M$  and  $\alpha$ . The chart indicates the proportion of a trait expected to be found in the material culture as a function of distance to the border.

Equation (6) predicts that along the border of Judah one should find both potteries: Philistine and Israelite. However 5-10 km E of the border one expects no Philistine pottery. This is fairly consistent with the maps of figures 19.2 and 19.4 of FAUST (2008). Table 5 compares archaeological findings with the expected results of (6). Two sites are inconsistent: Beth-El and Tel-en Nasbeh. Both are Israelite settlements with «little Philistine pottery» (FAUST 2008, 210). Possible explanation could be either a transient positive transgression before reaching «transgression-free» equilibrium or a slight slip from «transgression-free» equilibrium to «endemic transgression equilibrium» (LIVNI, STONE 2015).

## 6. CATEGORY (D)

Category (d) is not testable. Nevertheless, the investigation indicates that essential elements of the germinating Israelite culture like the concepts

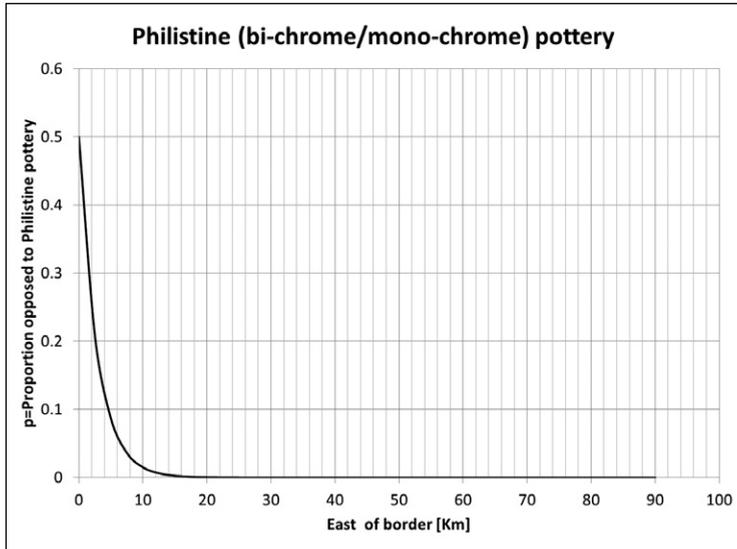


Fig. 7 – Pottery discontinuities – W of the border the Philistine pottery was contiguous; E of the border the opposition to it was contiguous; the curve shows the expected popularity to any rejected trait as a function of distance from the border; the curve is plotted using (6).

of covenant to which everyone is an equal signatory, of a Sabbath assembly, of minding others' business, of combating poverty and of dietary rules had to be brought by one single group of immigrants. Although contributions of other native or immigrant groups cannot be ruled out, this particular group played a dominant role in the birth of the Israelite covenantal culture.

## 7. CONCLUSIONS

The tests examined the compatibility of each category of theories with shared cultural traits and with the discontinuities of Table 1.

- Category (a) failed test 2. The test shows that these theories are incompatible with the borders of Fig. 2.
- Category (b) failed test 3. The test shows that Canaanite nomads that left traces of a ranked social structure could not transition fast enough into an egalitarian society because an immediate need for a developed egalitarian ethos and mechanisms of settling disputes.
- Category (c) passed tests 4 indicating no conflict between these theories and the borders of Fig. 2. This category also passed test 5 indicating that category (c) is compatible with the shared cultural traits of Section 2.

– Category (d) has not been tested. However the results of previous tests indicate that more a category (d) theory approaches category (c) the more it is consistent with simulated results.

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## ABSTRACT

Conflicting archaeological evidence has generated conflicting theories about Israel's origins. This work assembles all the theories into four categories and tests each category using computational tools borrowed from bio-mathematics. The bio-mathematical tools are models of diffusion, contagion and epidemics adjusted by various researches to study cultural transmission, ethnic borders and justice administration. The mathematical tools help reconcile known conflicting archaeological evidence and examine two aspects of the evidence that have not been considered so far: the alignment of the borders between material cultures and the conflict between sedentary and egalitarian lifestyles. Theories of immigration of pastoralist nomads passed the test.