Cognitive constraints on theories and category structure in the twelfth-century Arabic agricultural manual of al-Ṭiġnarī[1]

Phoebe Luckyn-Malone, University of Cambridge (pell2@cam.ac.uk)

Abstract This study investigates the role of cognitive bias in the development of scientific knowledge by examining the representation of natural phenomena in the Andalusī agricultural manual of al-Ṭiġnarī (*fl.* 480/1087). The article argues that psychological essentialism was a fundamental constraint on Ṭiġnarī's conceptualization of natural phenomena and on how he formulated botanical theories. The findings of this study suggest that psychological essentialism is a crucial factor in theory development and conceptual change in the study of living organisms.

Keywords Arabic science, history of agriculture, Muḥammad b. Mālik al-Ṭiġnarī, natural kinds, psychological essentialism.

Resumen Este estudio investiga el papel de los sesgos cognitivos en el desarrollo del conocimiento científico mediante el análisis de las representaciónes de fenómenos naturales en la obra agronómica andalusí de al-Ṭiġnarī (*fl.* 480/1087). El artículo argumenta que el esencialismo psicológico constriñó de manera fundamental la conceptualización de fenómenos naturales de al-Ṭiġnarī y su formulación de teorías botánicas. Los resultados de este estudio sugieren que el esencialismo psicológico es un factor crucial en el desarrollo de teorías y en el cambio conceptual en el estudio de los organismos vivos.

Palabras clave ciencia árabe, tipos naturales, esencialismo psicológico, historia de la agricultura, Muḥammad b. Mālik al-Ṭiġnarī.

Introduction

Amongst the Andalusī agricultural works produced in the eleventh and early twelfth centuries, none offers a more fascinating insight into contemporary beliefs about natural phenomena than the *Kitāb Zuhrat al-Bustān wa-Nuzhat al-Aḏhān* (*The Book of the Brilliance of the Garden and the Recreation of Minds*). This manual was written by Muḥammad b. Mālik al-Ṭiġnarī (*fl.* 480/1087) and was presented to the Almoravid emir of Granada at some point between 501/1107 and 508/1114 (Ṭiġnarī 2006, p. 14). Frequently cited in the agricultural works of Ibn al-ʿAwwām and Ibn Luyūn, Ṭiġnarī's manual was later abridged and extracts were included in numerous compilations (Carabaza Bravo 1998).

Researchers studying disciplinary change in Andalusī agriculture and botany have neglected to take account of the role played by cognitive constraints in shaping scientific knowledge, despite the fact that this topic has received considerable attention in the wider field of history and philosophy of science (for instance, see

[1]This chapter draft has been accepted for publication in the proceedings of the Mediterráneos Conference, held at the CCHS-CSIC in Madrid, December 13–15, 2010.

Atran 1990; Carruthers, Stich, and Siegal 2002; Nersessian 2008). To address this gap in the literature, I wish to argue that one particular cognitive bias, psychological essentialism, had an enormous impact on Ṭiġnarī's conceptualization of natural phenomena and on how he formulated theories about plants. I begin by identifying the essentialist assumptions that underpinned his knowledge and reasoning, before going on to investigate the role of these assumptions in his theorizing about the agricultural technique of grafting.

1 Essentialism and Ṭiġnarī's Natural Categories

Ṭiġnarī relied on a set of core assumptions about natural kinds that collectively constitute psychological essentialism. Essentialism is a cognitive bias that centres on the human predisposition to believe that a hidden causal essence is responsible for the properties of certain categories (Ahn et al. 2001; Coley, Medin, and Atran 1997; Gelman 2003; Medin and Atran 1999). However, essentialism is simply a skeletal framework, which means that a person doesn't necessarily know, either consciously or unconsciously, what the essence is (Gelman 1990; Medin 1989; Waxman, Medin, and Ross 2007). Diesendruck and Gelman have therefore proposed that 'this belief can be considered an unarticulated heuristic rather than a detailed theory' (1999, p. 88). While the actual existence of essences is widely rejected today, people have long assumed that they exist for a broad spectrum of categories, ranging from ethnic groups to natural substances, genders and plant species. The labels given to essences may vary across individuals and can differ between languages, but common examples in English include 'soul', 'nature' and 'life force'.

To conduct this study I examined the categories used by Ṭiġnarī to represent natural phenomena in order to identify the assumptions that informed his knowledge and reasoning about them. This approach was adopted based on Murphy and Medin's (1985) argument that a person's theories (in this case, essentialism) and background knowledge play a major role in determining the categories they generate. My interpretive framework for analysing these categories has been S. Gelman's (2003) model of essentialism, which remains the most comprehensive, empirically-based account of the theory to date, and I have largely adhered to her terminology to describe components of the theory. The relevant natural kind categories in Ṭiġnarī's text are those that represented living organisms (such as 'fig', *al-tīn*) and natural substances (such as 'water', *al-mā'*).

I have identified six essentialist assumptions about natural kinds in Ṭiġnarī's text. These are the beliefs that natural kinds have inductive potential, nonobvious properties, stability over transformation, sharp boundaries, innate potential, and causal features. I will now discuss each of these assumptions in turn.

1.1 A Causal Essence

Ṭiġnarī assumed that essences existed for a broad range of categories, but this belief was often an unconscious one and the essences themselves were rarely mentioned. However, there were occasions when he did articulate the existence of an essence and identified it by name, such as in the following passage (2006, pp. 56–57):

> [...] which is to say that the plant (*al-nabāt*), and each multiplying thing (*kulla šay'in nāmin*), God has made a living nature (*ṭabīʿa ḥayya*) requiring nourishment for [them], similar to the compound faculty (*al-quwwa al-murakkiba*) in the liver of animals (*al-ḥayawān*) which transforms nourishment into blood and makes what it feeds on similar to it. And by means of this faculty which God Most High inserted into the plant, nutrition is attracted from the soil and moistures generated from rains and waters. So that which agrees with [the plant's] nature (*ṭabʿahu*) and resembles its substance (*ǧawharahu*) is attracted by means of [this faculty], and in that manner the growth of [the plant's] body (*ǧismihi*) occurs. And this nature (*al-ṭabīʿa*) is like the air (*al-hawā'*) and the leaves on trees occur by means of it. And were it not [the case] that God inserted this faculty in all plants, then some [plants] would not surpass others, and their kinds (*anwāʿuhā*) would be one; but [God] the Beneficent—there is no Lord but He—did make this faculty in all plants [...]

The manifestation of essentialism is context-dependent (Diesendruck 2001) and in this instance Ṭiġnarī expressed his belief in essences through the terminology of contemporary Arabic philosophy and medicine: he used the label *ṭabīʿa* ('nature') to refer to the essence in plants and multiplying things.[2] Furthermore, Ṭiġnarī's religious commitments were reflected in his assertion that God had placed the 'nature' in each multiplying thing, a claim which, more generally, implied that the essence was intrinsic to the entity, rather than something invented by human beings or brought about by environmental conditions.

Regarding the qualities of essences, Ṭiġnarī's only direct statement on this subject was to suggest that the essence was unseen: he wrote that 'this nature is like the air' (*wa-haḏihi 'l-ṭabīʿa munāsabat al-hawā'*), a comment which accords with the descriptions of adults studied by developmental psychologists, who have described essences as 'invisible, distinct from outward appearances, and remarkably stable and resilient' (Gelman 2003, p. 60).

Implicit in the idea of essence is the notion that there is an 'executive cause' which explains a category's properties (Barrett 2001; Diesendruck and Gelman 1999; Medin and Ortony 1989), and those properties believed to be generated by the essence are called 'essentialized' in the literature (Barrett 2001, p. 5). In the present example, Ṭiġnarī believed that the 'nature' generated the properties of the category 'plant'. Specifically, he stated that the *ṭabīʿa* causes the following processes and physical properties:

- it attracts nutrition from the soil (*wa-bi-haḏihi 'l-quwwa allatī rakkaba 'llāhu taʿālā fī 'l-nabāti tuǧḏabu min al-arḍi 'l-ġiḏā'*);
- it attracts substance similar to it, a process which brings about growth (*fa-yuǧḏabu bi-hā mā yuwāfiqu ṭabʿahu wa-yušākilu ǧawharahu, wa-bi-ḏālika yakūnu numū ǧismih*); and,
- it brings about the leaves on the trees (*wa-bi-hā yakūnu 'l-waraqu fī 'l-ašǧār*).

[2] On the term *ṭabīʿa*, see Pingree and Haq 2011.

Ṭiġnarī's belief that a causal essence generated the properties of a kind is also indicated by his remarks on fruit stones and seeds. He believed that the 'action of the nature' (*fiʿlu 'l-ṭabīʿa*) within an entity, such as a fruit stone or child, brought about the manifold changes involved in its growth along with the properties associated with its mature form (pp. 267–68, 276). In other words, Ṭiġnarī not only believed that natural kinds such as plants, animals and human beings possessed an essence, but that their essences generated the characteristic properties of each of their kinds. A belief in a causal essence is the first core assumption of essentialism evident in his text.

1.2 Nonobvious Properties

The second core assumption of essentialism found in Ṭiġnarī's manual is that members of a category share hidden, nonobvious properties. He made this assumption when describing the properties of the category 'plant' generated by its 'nature' which were discussed in the previous section. That is, only one of the three properties caused by the 'nature' or essence was perceptible (i.e., the generation of leaves) while the rest were hidden processes and properties. Similarly, Ṭiġnarī's inferences from animal to plant properties in the same passage could not have been based on observation alone, because the transformation of nutrition into blood by the liver was in no way perceptible.

Another aspect of Ṭiġnarī's assumption of nonobvious properties was the importance he gave to insides or internal parts when reasoning about categories. He suggested that the 'living nature' (*ṭabīʿa ḥayya*) in plants and the 'compound faculty' (*quwwa murakkiba*) in animals were located inside the organism. In the same way, a basic association between insides and the generation of a natural kind's properties has been observed in children (Gelman and Wellman 1991; Gottfried and Gelman 2005).[3]

1.3 Inductive Potential

The third core assumption of essentialism apparent in the text is inductive potential, and whenever Ṭiġnarī used category-based induction (i.e., generalizing from one category to another) he relied on this assumption. It is widely agreed that one of the primary functions of essentialized categories is to permit inferences that move from the known to the unknown, and category-based induction permits reasoning about hidden properties as well as surface ones, based on the belief that natural kinds share nonobvious properties (Atran 1990; Barrett 2001; Coley, Medin, and Atran 1997; Gelman 2003; Gelman and Wellman 1991). One example from the passage quoted above (see section 1.1) concerns Ṭiġnarī's reasoning about the properties of plants. It was only possible for him to draw an analogy between 'animals' (*al-ḥayawān*) and 'plants' (*al-nabāt*), because he believed them both to be members of the higher-level category 'multiplying thing' (*šay'un nāmin*) and therefore to both share nonobvious properties.

1.4 Innate Potential

The fourth core assumption of essentialism evident in Ṭiġnarī's manual is innate potential. Throughout Ṭiġnarī's chapters on propagating plants there was no

[3]Gelman (1990) has dubbed this the 'causal innards principle'.

question that a seed taken from a plant would grow into anything other than that exact type of plant. Thus a date stone grows into a date palm (pp. 277–81); a fig seed grows into a fig tree (pp. 293–96); and an almond nut grows into an almond tree (pp. 304–06). These are an example of the general expectation that nature is a better indicator of category identity than nurture for natural kinds. Similar results have been found by Gelman and Wellman (1991) in a set of experiments involving plants. They found that children expected seeds taken from an apple to grow into an apple tree—not into flowers.

In connection with experimental studies, Gelman (2003) has noted an important aspect of the belief in innate potential. People's assumptions share three features: 'the essence is *transferable*, thereby accounting for how new members of a kind acquire their characteristics; transfer takes place *early in development*, so that the individual has the relevant properties in a formative period; and once the transfer has been accomplished, it is extremely *difficult to remove or change*' (p. 105). Ṭiġnarī did not explain the transfer process between a plant and its seed, but at the beginning of his article on seeds he wrote (2006, p. 267):

> All of the ancient natural philosophers [considered] that each fruit (*ṯamar*) is generated from the subtlety (*al-luṭf*) that reaches the plant from the matter of its nutrition (*min ǧawhari ġiḏā'ihi*). And their evidence of this is of the clearest indication and the strongest demonstration because they said that we have found all seeds [to] fall to the earth. So it is inevitable that what resembles its temperament (*mizāǧ*) of the materiality of the earth (*ǧawhariyyati 'l-arḍ*), and the humidity of water (*wa-ruṭūbati 'l-mā'*), is attracted to it from what its nutrition and existence [bring] it until [the time] when [that part of the seed that] the soil is next to has become moistened and has inflated, splitting open.

Thus, it appears that Ṭiġnarī assumed that a seed's temperament was already within it before it separated from the plant and fell to the ground. His position rested on the belief that the seed had innate potential and that it received its essence at an early stage in its lifecycle.

1.5 Stability over Transformation

The fifth core assumption of essentialism found in Ṭiġnarī's text is stability over transformation. When it came to natural kinds, he believed in the persistence of category identity over transformation—even in instances involving perceptual changes. This assumption is evident throughout all of his chapters on propagating plants. For example, when describing how to plant acorns (pp. 299–300), Ṭiġnarī specifically mentioned, or alluded to, several distinct forms that the oak passed through during its lifecycle:

- the acorn (*yaǧibu an yuzraʿa ḥabbu al-ballūṭ [...]*);
- the seedling (*[...] wa-urġidat ḥattā tanbuta wa-tartafiʿa bi-qadri 'l-iṣbaʿ*); and,
- the tree (*wa-šaǧaru 'l-ballūṭi yatarakkibu [...]*).

In other words, he assumed that despite the widely differing appearance of acorn, seedling and tree, these were all still members of the category 'oak'.

Similar expectations of kind stability have been found in children as young as three years old (Rosengren et al. 1991).

1.6 Sharp Boundaries

The sixth core assumption of essentialism apparent in the manual is that natural kind categories have sharp boundaries. Diesendruck and Gelman (1999) have found that adults consider category membership to be more absolute for animals and more graded for artifacts, suggesting that the boundaries for natural kinds are more clear-cut than for other categories. This corresponds closely with what we find in Ṭiġnarī's manual. For example, in his chapters on propagating plants, the boundaries of the category 'oak' (*al-ballūṭ*) remained stable despite the perceptual changes in the appearance of the oak during its lifecycle.

A second way in which category boundaries are reinforced is to believe that an entity is either a member of a category or it is not, it cannot be in-between (Malt 1990). Most of the time, Ṭiġnarī believed that the boundaries separating natural kinds were sharp, not fuzzy or graduated. For example, it is invariably the case in his text that a plant is either one kind or another. A particular plant was either an 'oak' or an 'elm', but it was never a partial example of either.

It is only in recent history that the metaphysical reality of category boundaries for living organisms has been questioned (for instance Ghiselin 1997; Ayala and Arp 2009, pp. 87–122), and children and adults untrained in modern science still tend to believe that natural categories represent real discontinuities in nature. As indicated by the passage quoted in section 1.1, Ṭiġnarī believed that God had placed the 'living nature' in plants and that this act had brought about the differentiation of plants into multiple kinds. Thus, he not only believed that God and the division of plants were real, but by implication he also accepted that the boundaries between those divisions were real.

Summary

This study has identified six core assumptions about natural phenomena in Ṭiġnarī's agricultural manual. He posited a hidden, causal essence in living organisms that was responsible for generating their properties, both surface and underlying. He also assumed rich inductive potential for natural categories: members of a category were believed to share hidden, nonobvious properties. Furthermore, he placed the location of this essence within the organism, not outside or elsewhere. Ṭiġnarī took it for granted that natural kinds have innate potential and he believed that category identity was stable over transformations such as growth. Finally, he treated the boundaries between natural kinds to be sharp, not fuzzy, and he believed them to be real. These assumptions—which collectively constitute psychological essentialism—functioned as heuristics that guided Ṭiġnarī's representation of knowledge about living organisms and his reasoning about them.

These findings suggest that essentialism was a fundamental constraint that shaped Ṭiġnarī's conceptualization of natural phenomena. Furthermore, the evidence reviewed here demonstrates that his reliance on essentialist assumptions when thinking about natural kinds was not only a feature of his implicit beliefs, but was also an important part of his explicit descriptions and explanations. I

will now turn from this analysis of Ṭiġnarī's essentialism to consider what role these assumptions played in the development of his theories.

2 Essentialism and Ṭiġnarī's Grafting Theories

The focus of this section is Ṭiġnarī's critique of a claim made by the *Nabatean Agriculture* about grafting, a case which demonstrates that an appreciation of Ṭiġnarī's essentialism improves our ability to explain his explicit beliefs and theories (2006, p. 378):

> And as for the author of the *Nabatean Agriculture*, he alleged that a graft of citron (*al-utruǧǧ*) onto olive (*al-zaytūn*) would yield black citrons (*al-utruǧǧ al-aswad*). And someone else mentioned that a graft of apple (*al-tuffāḥ*) onto oleander (*al-diflā*) would [result in] a bitter apple (*tuffāḥan murran*). And in my opinion this is impossible, because the grafted rootstock gives neither scent, nor colour, nor taste. Rather, it sends simple matter (*mādda mufrada*) to what is grafted onto it [i.e., to the scion], and the grafted scion transforms the matter into form and changes it until it resembles [the scion].

Ṭiġnarī's representation of the views expressed in the *Nabatean Agriculture* was not verbatim (*bi'l-lafẓ*), but it could be considered paraphrastic (*bi'l-maʿnā*) in light of a similar statement in the *Nabatean Agriculture* where the graft of a pear (*al-kummaṯrā*) onto citron was said to produce a pear with the colour and scent of a citron (Ibn Waḥšiyya 1993, p. 1289). Moreover, while it was never claimed in the *Nabatean Agriculture* that the outcome of grafting citron onto olive was black citrons, it was nonetheless stated that there would be a change in the attributes of the resulting fruit—the citron's shape would be like an olive and its colour would be 'between red and yellow' (pp. 13–14).

But regardless of the faithfulness of Ṭiġnarī's paraphrase, his disagreement with the *Nabatean Agriculture*'s account of grafting is perplexing given that the technique was an observable, physical procedure, not a theoretical notion. Can an understanding of Ṭiġnarī's essentialist beliefs help explain the conflict between the two accounts and resolve apparent contradictions in Ṭiġnarī's own descriptions of grafting?

2.1 Explaining Ṭiġnarī's Refutation of Black Citrons

The *Nabatean Agriculture*'s account of grafting emerged in the context of much earlier belief systems (Hämeen-Anttila 2006) and from Ṭiġnarī's critical remarks it does not appear to have been comprehensible in terms of his own conception of the procedure. He therefore deemed its claim to be 'impossible' (*mustaḥīl*). My analysis of Ṭiġnarī's grafting chapters reveals that he disagreed with the *Nabatean Agriculture* not only because its claim conflicted with his practical experience, but because it also violated his essentialist assumptions.

The reasoning that Ṭiġnarī used to justify his criticism provides an important indication that the *Nabatean Agriculture*'s report of black citrons contradicted his own observations and experience (2006, pp. 378–79):

> And were the rootstock onto which [the scion] has been grafted to give colour, taste or scent, then that which has been planted in

> salty soil would become salty—especially the [kind of] fruit that only thrives in salty soil. And we see that the situation is different to that, and we may graft the sweet onto the sour and the sour onto the sweet, but in regard, the fruit will only be an attribute of the grafted bud, be it sweet, bitter or sour.

In other words, despite the breadth of Ṭiġnarī's experience with grafting, the *Nabatean Agriculture*'s account did not correspond to any scenario that he had ever observed or imagined to be possible.

Furthermore, an analysis of the plant categories mentioned in this dispute suggests that the *Nabatean Agriculture*'s claim about grafting also conflicted with Ṭiġnarī's essentialist assumptions about natural kinds. The crux of the disagreement between them was whether or not kinds such as 'citron' (*al-utruǧǧ*) and 'olive' (*al-zaytūn*) retained their identity during the process of grafting. For instance, Ṭiġnarī's remarks clearly express his belief that a grafted citron scion remained a citron, and that a grafted olive rootstock remained an olive. This belief was consistent with his general expectation that natural kinds remained stable over transformation, as discussed in section 1.5. However, the claim of the *Nabatean Agriculture* conflicted with his assumptions about the categories 'citron' and 'olive'. Firstly, its claim implied that these natural kinds were fundamentally altered by the grafting process (i.e., that the citron did not remain quite a citron, and the olive did not remain quite an olive), which was contrary to Ṭiġnarī's assumption of kind stability. Secondly, its claim implied that these two natural kinds had merged or mixed during grafting to produce something like a citron-olive hybrid-an implication which ran counter to Ṭiġnarī's general assumption that the boundaries between natural kinds were discrete and sharp, as discussed in section 1.6. I would therefore argue that Ṭiġnarī not only rejected the *Nabatean Agriculture*'s claim about black citrons because it conflicted with his practical experience, but because it also violated his essentialist assumptions about natural kinds.

2.2 Resolving Contradictions in Ṭiġnarī's Descriptions of Grafting

While an appreciation of Ṭiġnarī's essentialism can add explanatory depth to our understanding of his theories about grafting, I wish to argue that there are also occasions where those theories can only be understood by appreciating the role of his essentialist assumptions. For instance, there were contradictions in Ṭiġnarī's position in relation to whether the rootstock could affect the properties of the scion. As part of his criticism of the *Nabatean Agriculture*'s claim about grafting, he denied that such a thing was possible—the rootstock did not affect scent, colour or taste (p. 378). But elsewhere in the text, he suggested that the rootstock could indeed affect the properties of the scion by making it fruit earlier (p. 362). How can this discrepancy be explained?

As discussed in section 1.1, psychological essentialism entails the belief that things 'have essences or underlying natures that make them the thing that they are' (Medin 1989, p. 1476), and the properties believed to be generated by the essence are called 'essentialized'. My proposal for reconciling Ṭiġnarī's contradictory remarks is to recognize the implicit distinction in his representation of the scion's properties: he essentialized some properties, but assumed others

were merely accidental to the kind.

If Ṭiġnarī believed that a scion retained its kind identity during grafting, then he also assumed that its essentialized properties remained unchanged. This is because those properties would continue to be generated by the same essence. Now given Ṭiġnarī's statement that the rootstock gave neither colour, taste, nor scent, it follows that he considered these three attributes to be kind-specific, essentialized properties. On the other hand, his suggestion that the rootstock could affect the time of fruiting—in other words, that the essence of one kind could generate the properties of another kind grafted onto it—can be reconciled with his belief in stable kind identity if we identify this property as accidental. This is because kind identity is determined by essentialized properties (not accidental ones), so a change in accidental properties would not necessarily entail a change in identity. I would therefore argue that interpreting colour, taste and scent as essentialized properties, and time of fruiting as an accidental property, is consistent with Ṭiġnarī's belief in stable kind identity during grafting, which would resolve the apparent contradictions in his text.

Summary

This analysis has found that Ṭiġnarī's assessment of the *Nabatean Agriculture*'s claims about grafting, and his alternative theory, were not only informed by his past experience and observations, but were additionally constrained by his essentialist beliefs about natural kinds. I have also argued that the seemingly contradictory statements that Ṭiġnarī made about grafting were actually compatible from his own essentialist perspective.

Conclusion

This brief examination of Ṭiġnarī's essentialism shows us how much his assumptions about natural phenomena can tell us about the way his mind represented reality. Psychological essentialism not only constrained his knowledge about living organisms and natural substances, but also implicitly guided his theorizing. Although space constraints have limited the number of examples cited, the presence of similar material throughout Ṭiġnarī's text constitutes strong evidence for these findings. Moreover, Ṭiġnarī was not unique in his essentialist bias: I have uncovered similar beliefs in other Andalusī agricultural manuals, such as those of Ibn al-ʿAwwām and Ibn Luyūn. There is therefore great scope for further work on the use of natural categories in these texts.

More broadly, this study has demonstrated that the framework provided by psychological essentialism is an invaluable aid to uncovering the process of theory formation in disciplines concerned with natural phenomena. The study has also shown how essentialism can serve as a powerful presupposition for individuals untrained in modern science. Furthermore, these findings raise the question of whether a predisposition to believe in causal essences has been a contributing factor in the desire of human beings to understand natural processes throughout history. Psychological essentialism should therefore be an integral part of historical and philosophical research into the study of the natural world.

References

Ahn, Woo kyoung et al. (2001). "Why essences are essential in the psychology of concepts". In: *Cognition* 82, pp. 59–69.

Atran, Scott (1990). *Cognitive Foundations of Natural History. Towards an anthropology of science*. Cambridge University Press.

Ayala, Francisco J. and Robert Arp, eds. (2009). *Contemporary Debates in Philosophy of Biology*. Oxford: Wiley-Blackwell.

Barrett, H. Clark (2001). "On the functional origins of essentialism". In: *Mind and Society* 2, pp. 1–30.

Carabaza Bravo, Juliá (1998). "Códices misceláneos de agronomía anadalusí". In: *Al-Qanṭara. Revista de Estudios Arabes* 19, pp. 393–416.

Carruthers, Peter, Stephen Stich, and Michael Siegal, eds. (2002). *The Cognitive Basis of Science*. Cambridge University Press.

Coley, J. D., D. L. Medin, and S. Atran (1997). "Does rank have its privilege? Inductive inferences within folkbiological taxonomies". In: *Cognition* 63, pp. 73–112.

Diesendruck, G. (2001). "Essentialism in Brazilian children's extensions of animal names". In: *Developmental Psychology* 37, pp. 49–60.

Diesendruck, G. and S. A. Gelman (1999). "Domain differences in absolute judgments of category membership. Evidence for an essentialist account of categorization". In: *Psychonomic Bulletin and Review* 6, pp. 338–46.

Gelman, Rochel (1990). "First principles organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples". In: *Cognitive Science* 14, pp. 79–106.

Gelman, S. A. and H. M. Wellman (1991). "Insides and essences. early understandings of the nonobvious". In: *Cognition* 38, pp. 213–44.

Gelman, Susan A. (2003). *The Essential Child. Origins of essentialism in everyday thought*. Oxford University Press.

Ghiselin, Michael T. (1997). *Metaphysics and the Origin of Species*. Albany: State University of New York Press.

Gottfried, Gail M. and Susan A. Gelman (2005). "Developing domain-specific causal-explanatory frameworks. the role of insides and immanence". In: *Cognitive Development* 20, pp. 137–58.

Hämeen-Anttila, Jaakko (2006). *The Last Pagans of Iraq. Ibn Waḥshiyya and his Nabatean Agriculture*. Islamic History and Civilization. Studies and Texts. 63. Leiden: Brill.

Ibn Waḥšiyya (1993). *L'Agriculture Nabatéene. Traduction en arabe attribuée à Abū Bakr Aḥmad b. ʿAlī al-Kasdānī connu sous le nom d'Ibn Waḥšīya (IVe/Xe siècle)*. Ed. by Toufic Fahd. 3 vols. Damascus: Institut Français de Damas.

Malt, Barbara C. (1990). "Features and beliefs in the mental representation of categories". In: *Journal of Memory and Language* 29, pp. 289–315.

Medin, Douglas L. (1989). "Concepts and conceptual structure". In: *American Psychologist* 44 (12), pp. 1469–81.

Medin, Douglas L. and Scott Atran, eds. (1999). *Folkbiology*. Cambridge, MA: MIT Press.

Medin, Douglas L. and A. Ortony (1989). "Psychological essentialism". In: *Similarity and analogical reasoning*. Ed. by S. Vosniadou and A. Ortony. Cambridge University Press, pp. 179–95.

Murphy, Gregory L. and Douglas L. Medin (1985). "The role of theories in conceptual coherence". In: *Psychological Review* 92 (3), pp. 289–316.

Nersessian, Nancy J. (2008). *Creating Scientific Concepts*. Cambridge, MA: MIT Press.

Pingree, D. E. and S. Nomanul Haq (2011). "Ṭabīʿa". In: *Encyclopaedia of Islam*. 2nd ed. Leiden: Brill Online.

Rosengren, K. et al. (1991). "As time goes by. Children's early understanding of biological growth". In: *Child Development* 62, pp. 1302–1320.

Ṭiġnarī, Muḥammad b. Mālik (2006). *Esplendor del jardín y recreo de las mentes*. Ed. by Expiración García Sánchez. Fuentes Arábico-Hispanas 32. Madrid: Consejo Superior de Investigaciones Científicas.

Waxman, Sandra, Douglas Medin, and Norbert Ross (2007). "Folkbiological Reasoning From a Cross-Cultural Developmental Perspective". In: *Developmental Psychology* 43 (2), pp. 294–308.