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Shamanism or science?*

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ABSTRACT

The interconnection of the three organismic levels, metabolism, morphology, and biogeography, can now be amplified into a multipart architecture, introducing plant bioactivity through ethnobotany-oriented descriptions. Only via such an integrative model, the diverse organismic levels can be connected within a more holistic, realistic scheme. Construction of qualitative and quantitative models via evolutionarily conceived implantation into dahlgrenograms and Sporne indices, allows ethnobotany to acquire predictive validity. The coherence of such systems was demonstrated by comparison of the vast ethnobotanical Brazilian database by Pio Corrêa with relatively very minute databases referring to three Amazonian Indian societies.

Key words: ethnobotany, angiosperms, medicinal species, edible species, systematic trends, evolutionary trends, Chácobo, Kayapó, Ka'apor.

INTRODUCTION

Research on medicinal plants continues to be performed on the level of species, without any concern for the species' phylogenetic relationships. The sole concern that often serves to guide the choice of samples is based on popular orientations. The reason for this extraordinary confidence on traditional wisdom is due to the protracted time span these plants were essayed by successive generations of indigenous societies. On considerably greater scales, however, success of ethnobotany proved rather modest, and incompatible with the investment in time and effort.

Today basically the opinions concerning the most appropriate way to face the problem of medicinal plants comprise two opposed trends: one admits that answers will continue to be obtained preferentially by traditional knowledge, i.e. by accumulation of knowledge transmitted by generations, and another one indicates that definitive results will depend on progress in technical procedures of extraction, identification and bioessays of natural compounds. Only a scientific basis is capable of integrating the two partial visions, popular and technological information, allowing ethnobotanical descriptions to possess predictive value. This objective, nevertheless, presents the great challenge of integrating ethnobotanical and scientific knowledge at the level of a chemobiological language for the search of trends and patterns of functioning of nature.

BACKGROUND

A new holistic insight into the functioning of nature, in contrast to the traditional reductive approaches, requires integration of the basic levels of life's organization: metabolism, morphology and biogeogra-

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phy. Our previous papers demonstrated the possibility to reach this aim through two fundamental conditions: First, and most importantly, the characteristics of each level must be expressed by suitable parameters [such as numbers of occurrences (NO) and oxidation states (O) for compounds; Sporne indices (SI) and herbaceousness indices (HI) for forms, and taxonomic uniqueness (TU) and species dominance (SD) for spatial distribution]; Second, the mechanisms responsible for the connection among these different levels need be determined through their respective interface boundaries (such as membranes and cell walls at the metabolic and the morphologic levels, and ecotones at the biogeographical level) (Gottlieb and Borin 1999a, b).

This integrative model can be applied to clarify the mechanisms responsible for plant utility. Obviously all data utilized previously were measured by accurate scientific criteria, in contradistinction to ethnobotanical information, many times obscured by mysticisms and superstitions. It is important to note that an illness can have distinct meaning for each population. Likewise a plant can produce different compounds, and show different properties in various regions. Thus, how should we proceed to integrate traditional knowledge into the chemobiological framework?

This challenge question was answered in a previous paper by means of an adequate methodology, changing the qualitative, narrative informations on models to quantitative, dynamic ones. This procedure allowed to assign systematic and evolutionary trends in a vast Brazilian ethnobotanical survey (Gottlieb et al. 2001). The success obtained led to a new question: Do the observed patterns possess universal significance? Initially, to answer this question, we chose an appropriate database, not of continental size, as the former survey, but of smaller regionally restricted dimensions.

METHODS

Databases

This paper is based on data of plants utilized by three indigenous societies living in different parts of Amazonia: Chácobo (Bolivia), Kayapó (Xingú, Brazil) and Ka'apor (Maranhão, Brazil) (Table I).

Ethnobotanical Parameters – Qualitative Models

From each indigenous inventory the dicotyledon species, to which useful (e.g. food, medicine) properties had been assigned by ethnobotanical recommendation, were listed in their respective families and classified according to Dahlgren's system (Dahlgren 1980). Properties of dicotyledon orders by ethnobotanical informations were indicated on dahlgrenograms, utilizing different colors to illustrate the preponderant uses of their species as food, medicine, nutraceutic or poison (Fig. 1).

Evolutionary Parameter

The dicotyledon families that contain useful species cited in each ethnobotanical inventory were characterized by an evolutionary parameter based chiefly on morphologic characters, the Sporne index (Sporne 1980). The evolutionary status of the dicotyledon orders was attributed by the SI means of their families, considering only the families to which useful species had been assigned (Fig. 1, Table II).

Ethnobotanical Parameters – Quantitative Models

With the aim of quantifying the evolutionary trends for the ethnobotanical patterns, the dicotyledon families were classified according to their evolutionary status given by Sporne indices (see *Evolutionary Parameter*). In this procedure, the families are arranged in evolutionary groups (according to SI values) and not in the usual way, i.e. in systematical groups (in orders and superorders according to Dahlgren's classificatory system). The construction of the quantitative ethnobotanical models (''spectra'') leads to the determination of evolutionary patterns for each type of bioactivity, i.e. food and medicine (Fig. 2).

TABLE I

Number of useful dicotyledon species registered for three different Amazonian indigenous societies.

	Chácobo	Kayapó	Ka'apor
Reference	Boom 1989	Anderson and Posey 1989	Balée and Gély 1989
Distribution	Alto Ivón, Beni River, Bolivia	Southern Pará, Xingú River, Brazil	Northern Maranhão, Turiaçú River, Brazil
Habitat	Terra firme Amazonian rain forest	Tropical scrub savanna*	Terra firme Amazonian rain forest
Predominant management	Collecting	Cultivation	Cultivation
Food species	59	12	38
Medicine species	109	63	22
Nutraceutic species	23	17	7
Poisonous species	5		
Total of dicotyledon species	196	92	67

*Transition zone between the Amazonian dense forests and central Brazilian drier cerrados.

RESULTS AND DISCUSSION

The first attempts to validate ethnobotanical information utilizing the data based on three small human societies, revealed a close consistency of ethnobotanical data and Cronquist's classificatory scheme for angiosperms (Gottlieb and Borin 1997, Gottlieb et al. 1995). In the present work we submitted this same database to a still stronger integrative process, involving presumably phylogenetic evolutionary characteristics (via a dahlgrenogram), evolutionary parameters (via Sporne indices) in combination with bioactivity (via ethnobotany) in a dynamic framework. This approach, when applied previously to a vast ethnobotanical inventory, demonstrated the existence of systematic and evolutionary patterns (Gottlieb et al. 2001). Keeping in mind the differences in size and range of the two types of ethnobotanical inventories, identical patterns can be observed.

Qualitative Models

These similarities between the results obtained by the two types of databases can be noted in both qualitative (Fig. 1) and quantitative models (Fig. 2). In the former, the ethnobotanical data are coincident with the systematic and evolutionary distribution of angiosperm orders in a dahlgrenogram (Fig. 1). Thus, the three indigenous populations, as well as Pio Corrêa's survey (Gottlieb et al. 2001), describe for medicinal purposes more advanced taxa, mainly Asteridae sensu Cronquist (1988), displayed at the right bottom corner of the diagram. This fact is corroborated by the higher Sporne indices of the two major clusters of orders predominantly medicinal (SI $47-61 \rightarrow 57-75$, corresponding to pink bubbles, displayed from the left top to the right bottom corner in Fig. 1). In contradistinction, plants used for food purposes predominate in relatively more primitive clusters of orders (SI $44-51 \rightarrow 50$, corresponding to green bubbles displayed from the left bottom to the right top corner in Fig. 1).

The high degree of similarity between these results and the previous ones obtained with a more extensive database, is demonstrated by comparisons among the SI values and predominant uses for the pertinent food and medicine orders of both types of inventories (Table II). Thus, out of the 29 dicotyledon orders cited for both types of inventories, 16 (55%) show exactly the same preferential indications of use, and only one (Urticales) gives more

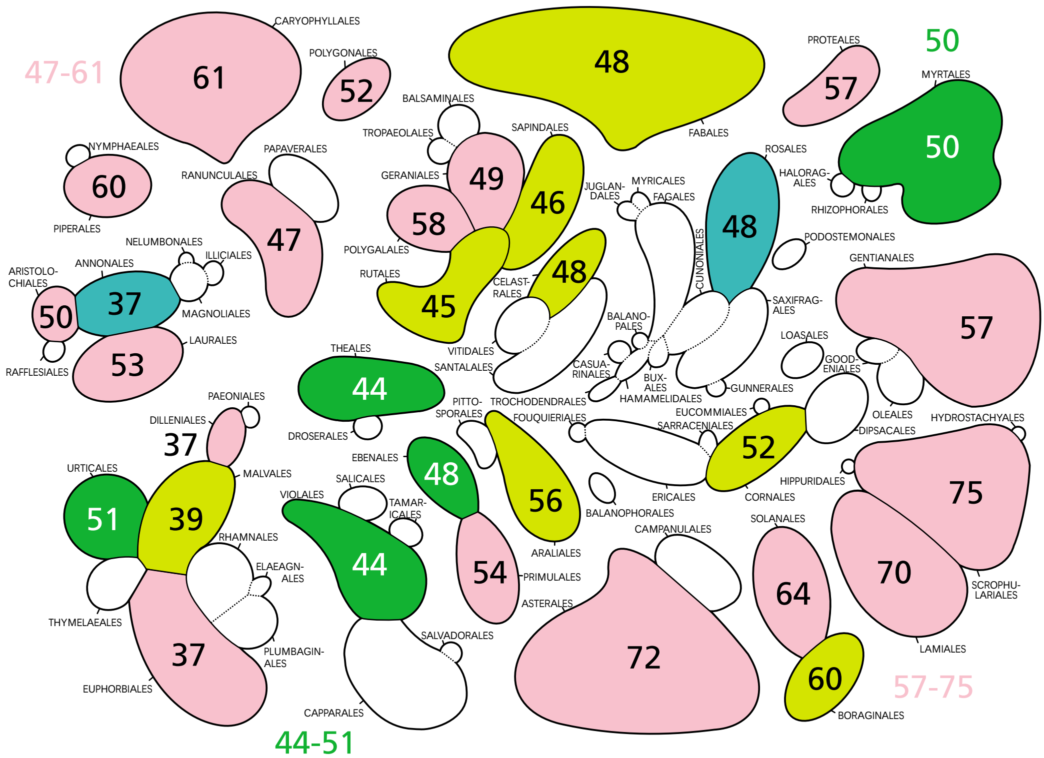

Fig. 1 – A dahlgrenogram (Dahlgren 1980) for dicotyledons, illustrating preferential uses of species in orders, represented by ‘‘bubbles’’, as foods (green), medicines (pink), foods and medicines (light green) and medicines and nutraceutics (Annonales) or foods, medicines and nutraceutics (Rosales) (cyan) based on the three Amazonian indigenous societies (Anderson and Posey 1989, Balée and Gély 1989, Boom 1989). The orders were characterized by an evolutionary parameter [Sporne (1980) indices], obtained by the means of SI of the pertinent useful families.

conflicting results, i.e. medicinal for Pio Corrêa and alimentary for indigenous societies. However, even in this case, the Sporne index is identical for both surveys.

Disagreements found could be explained by the regional availability of the plants in the case of smaller populations. The regional aspect of these data can be diagnosed by absence of representatives of several plant groups relatively rare in tropical regions, such as Papaverales, Ericales and Rosiflorae (colorless bubbles in Fig. 1). One of the pertinent examples constitutes the family Boraginaceae, order Boraginales, included in Asteridae, subclass above described as predominantly medicinal. Less frequent in tropical regions and found throughout temperate and subtropical areas (Heywood 1993), Chácobo utilize one species for medicinal purposes, and Ka'apor one species for alimentary purposes (light green bubble in Fig. 1). In contrast, Pio Corrêa quotes the utilization of 20 medicinal, one nutraceutical and two toxic species as belonging to this family (Gottlieb et al. 2001). Evidently this latter survey must include cultivated species, some transplanted from other regions. Another example refers to the absence of the groups to which Pio Corrêa attributed higher toxicity, such as Ranunculales, Papaverales and Ericales.

Rosiflorae are a further illustrative example.

TABLE II

Sporne indices (SI), number of species cited and predominant use for dicotyledon orders according to different ethnobotanical inventories [Pio Corrêa (PC) (Gottlieb et al. 2001), and three Amazonian indigenous societies (Ind) (in this paper)].

Superorder	Order	SI		No. spp cited		Predominant use	
(iflorae)	(ales)	PC	Ind	PC	Ind	PC	Ind
Magnoli	Illici	38		5		medicine	
	Magnoli	38		4		medicine	
	Annon	37	37	39	19	nutraceutic	medicine and nutraceutic
	Laur	50	53	35	8	medicine	medicine
	Aristolochi	50	50	41	1	medicine	medicine
	Rafflesi	75		1		food	
Nymphae	Nymphae	48		15		medicine	
	Piper	60	60	13	11	medicine	medicine
Ranuncul	Ranuncul	48	47	20	1	medicine and toxic	medicine
	Papaver	48		3		medicine and toxic	
Caryophyll	Caryophyll	57	61	56	6	medicine	medicine
Polygon	Polygon	52	52	13	3	medicine	medicine
Malv	Dilleni	37	37	1	2	medicine	medicine
	Euphorbi	37	37	71	13	medicine	medicine
	Malv	40	39	31	9	medicine	food and medicine
	Rhamn	45		6		medicine	
	Urtic	51	51	42	21	medicine	food
	Thymelae	55		1		medicine	
	Plumbagin	60		1		medicine	
Viol	Viol	45	44	88	19	food and medicine	food
	Salic	44		1		medicine	
	Capparid	56		23		food and medicine	
The	The	43	44	32	11	food and medicine	food
Primul	Eben	48	48	13	7	food and medicine	food
	Primul	54	54	5	4	food and medicine	medicine
Ros	Hamamelid	37		1		medicine	
	Fag	38		1		food	
	Jugland	50		1		food	
	Ros	43	48	41	4	food	food, medicine and nutraceutic
	Saxifrag	52		4		medicine	
Fab	Fab	48	48	206	30	food	food and medicine
Prote	Prote		57		1		medicine
Myrt	Myrt	52	50	110	32	food	food

TABLE II (continuation)

Superorder	Order	SI		No. spp cited		Predominant use	
(iflorae)	(ales)	PC	Ind	PC	Ind	PC	Ind
Rut	Rut	45	45	49	11	medicine	food and medicine
	Sapind	51	46	26	11	food and medicine	food and medicine
	Gerani	51	49	12	6	medicine	medicine
	Balsamin	57		1		medicine	
	Polygal	58	58	26	21	food and medicine	medicine
Santal	Vitid	41		8		medicine	
	Celastr	47	48	12	4	food and medicine	food and medicine
	Santal	56		5		medicine	
Balanophor	Balanophor	64		2		medicine	
Arali	Arali	56	56	25	3	food and medicine	food and medicine
Aster	Campanul	63		10		medicine	
	Aster	72	72	111	4	medicine	medicine
Solan	Boragin	60	60	23	2	medicine	food and medicine
	Solan	64	64	79	10	medicine	medicine
Corn	Eric	45		7		toxic	
	Corn	56	52	15	3	food	food and medicine
	Dipsac	74		7		medicine	
Gentian	Gentian	58	57	144	38	medicine	medicine
	Ole	62		3		food and medicine	
Lami	Scrophulari	72	75	58	13	medicine	medicine
	Lami	70	70	80	6	medicine	medicine

Pio Corrêa's survey presents indications of use for 46 species included in six families of this superorder. Chácobo and Kayapó furnished five indications for species included in two major genera, Hirtella and Licania (native to low regions of tropics and subtropics), of only one family, Chrysobalanaceae, belonging to the Rosiflorae. It is worthwhile to mention that this family is not listed among the six cited by Pio Corrêa. It is nevertheless surprising that practically the same pattern of use, i.e. intermediate between alimentary and medicinal, is observed for the species of this superorder in both types of inventories (Table II). Thus, although according to Pio Corrêa, Rosales are considered predominantly alimentary (i. e. show a relation of food/medicine/nutraceutic/toxic species of 25/14/1/1), other orders such as Saxifragales and Hamamelidales present a stronger relation of medicinal species (0/3/0/1 and 0/1/0/0 respectively). On the other hand, for the indigenous populations the predominant use of species of Rosales is indistinguishable among food, medicine or nutraceutic (1/2/2; cyan in Fig. 1). This demonstrates the low toxicity of this group, as has already been noted for the data listed by Pio Corrêa's survey.

The case of the Rosiflorae illustrates two important topics that merit to be considered. First, this taxon possesses a clear intermediate position between the alimentary cluster incorporating Fabales and Myrtales (within the right upper corner of the dahlgrenogram), and the medicinal cluster formed by the orders collectively called Asteridae (at the lower right corner of the dahlgrenogram). Again

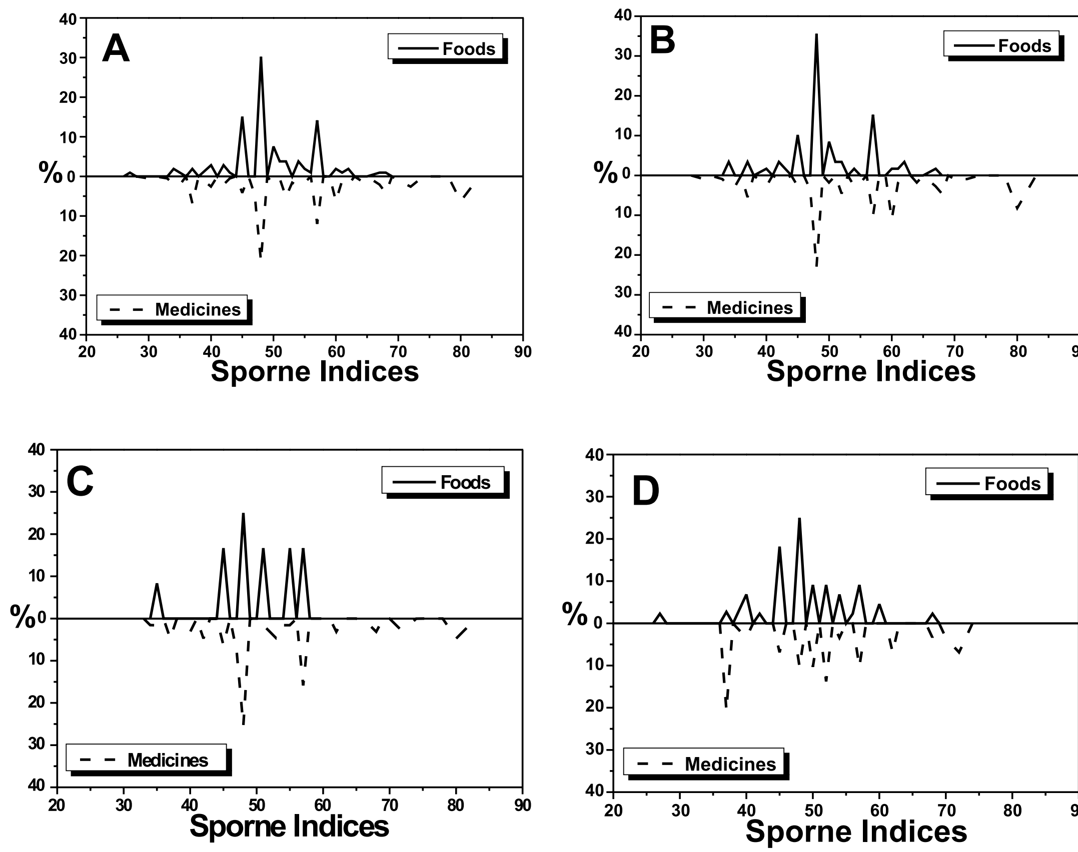

Fig. 2 – Evolutionary spectra indicating, for each evolutionary status [described by SI (Sporne 1980)], the number of species (in percentage values) qualified as foods (full lines in the top part of the ''spectra'') and as medicines (dashed lines in the bottom part of the ''spectra'') in ethnobotanical inventories: **A.** all the three Amazonian indigenous societies (Chácobo, Kayapó and Ka'apor); **B.** Bolivian Chácobo (Boom 1989); **C.** Brazilian Kayapó (Anderson and Posey 1989); **D.** Brazilian Ka'apor (Balée and Gély 1989). Normalisation was effected considering the total number of species cited for each ethnobotanical application (foods and medicines).

this position is perfectly acceptable from the evolutionary point of view in angiosperms (Cronquist 1988). Second, the example allows to validate the methodology and generality of the systematic and evolutionary patterns previously observed (Gottlieb et al. 2001). Even in the absence of citation of Chrysobalanaceae in Pio Corrêa's inventory, their species are used by indigenous populations according to the expected pattern of this taxonomic group.

Quantitative Models

The evolutionary patterns assigned to useful species through the qualitative model can be quantified by ''spectral'' models utilizing SI as a classificatory criterion for angiosperm families (Fig. 2). These quantitative ethnobotanical models allowed determination of evolutionary patterns for each type of bioactivity, in this case food and medicine. Thus, while food species are usually characterized by intermediate SIs (major peaks close to 50; full lines in the upper part of Fig. 2), medicine species show a larger SI range reaching the higher values (close to 80; dashed lines in the lower part of Fig. 2). These suggestive patterns should have been more clearly noted by the classification of dicotyledon orders according to predominant use of their species (Table III).

Again the similarities between these results and

TABLE III

Minimum and maximum values of Sporne indices for dicotyledon orders according to their predominant use cited in different ethnobotanical inventories.

Predominant use	Ranges of Sporne indices		Colors in Fig. 1
	Pio Corrêa (Gottlieb et al. 2001)	Amazonian Indigenous†	
Food	38–56 (75)‡	44–51	green
Food and medicine	43–62	39–56 (60)*	light green
Medicine	37–74	37–75	pink

†Table II, Fig. 1; ‡SI = 75 refers to only one food species of Hydnoraceae (Rafflesiales); see Table II; and *SI = 60 refers to Boraginaceae (Boraginales). For details see discussion in text of Results and Discussion.

the ones obtained by analyses of a vast survey are obvious (Tables III, IV). These correspondences become more evident when the three indigenous populations are considered collectively (Table IV, Fig. 2A) rather than individually (Table IV, Fig. 2B-D). Many features distinguish each human group, from the environmental point of view, as available resources, type of vegetation, climate and soil, to the sociocultural point of view, as management strategies, nutritional customs, inheritance of the traditional use of plants, illness characterizations and even mystic beliefs (Table I). All these characteristics should be responsible for the differences observed among their spectral patterns (Fig. 2). Thus, for instance, the nature of the Ka'apor as cultivators should explain the higher range of SI reached by their food families (Table IV, Fig. 2D), as well as the extraordinary intensity of all peaks (above 8%) of food families consumed by the Kayapó (Fig. 2C). The spectral features of useful plants for Chácobo, essentially collectors, are more similar to the features noted for populations covered by Pio Corrêa's survey (Gottlieb et al. 2001) (Fig. 2B). After all, however, in spite of each community to possess differences and limitations, the spectral similarities to their useful plants are striking.

CONCLUSION

The data on plant uses are based on the traditional interviews, and hence their consistence with the distribution of superorders in Dahlgren's scheme, or even with evolutionary patterns as well as its correspondence with an extensive inventory is truly astounding. Thus, rather than exclusively providing the methodologic power to validate systematic and evolutionary patterns of plant bioactivity, this achievement introduces a new dimension into the chemobiologic network, ethnobotany (Fig. 3). Only via such a multipart architecture integrative model, measurements of influences caused by each organizational levels as well as simulations into the mechanisms of functioning of nature becomes possible.

Indeed, the biological functions of plants are very complex, regulated by their chemical arsenal, in rigorous connection with environmental fluctuations. The numerous facts involved make the predictions of metabolic and hence, morphological variability a laborious task. Presently, the situation is becoming even more serious through the increasing rate the environment is suffering natural and/or artificial modifications. Nevertheless, discussions on medicinal plants have continued without substantial alterations for many years. Thus we consider the problem to lack scientific understanding of the mechanisms regulating production, storage and ex-

TABLE IV

Minimum and maximum values of Sporne indices for food and medicine dicotyledon families according to their use cited in different ethnobotanical inventories.

Ethnobotanical inventories	Ranges of Sporne indices		
	Food	Medicine	
Pio Corrêa	27–80*	25–87	(Gottlieb et al. 2001)
Chácobo + Kayapó + Ka'apor	27–68	30–80	Fig. 2A
Chácobo	34–67	30–80	Fig. 2B
Kayapó	35–57	34–80	Fig. 2C
Ka'apor	27–68	37–72	Fig. 2D

*SI = 80 refers to only one food species of Bignoniaceae, a typical medicinal family (32 medicine species).

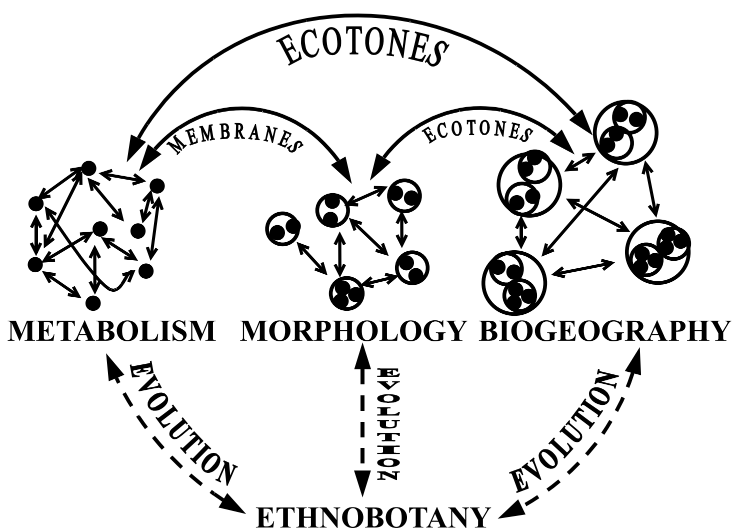

Fig. 3 – Scheme illustrating the integration of the ethnobotanical information, through evolutionary patterns, into the chemobiology network symbolized by the connectivity among three organizational levels of life, metabolism, morphology and biogeography, and mediated by membranes and ecotones.

pression of these bioactive substances. But this is another story...

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RESUMO

A conexão entre os três níveis organísmicos, metabolismo, morfologia e biogeografia, pode ser agora ampliada em

uma arquitetura múltipla, introduzindo bioatividade vegetal através de descrições etnobotânicas. Somente através de tal modelo integrativo, os diversos níveis organísmicos podem ser conectados dentro de um esquema holístico mais realista. Construção de modelos qualitativos e quantitativos via dahlgrenogramas e índices de Sporne, ambos concebidos evolutivamente, permite que etnobotânica adquira validade de previsão. A coerência de tais sistemas foi demonstrada por comparação entre uma grande base de dados etnobotânicos brasileiros, publicada por Pio Corrêa, com bases menores, restritas a três sociedades indígenas da Amazônia.

Palavras-chave: etnobotânica, angiospermas, plantas medicinais, plantas alimentícias, tendências sistemáticas, tendências evolutivas, Chácobo, Kayapó, Ka'apor.

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