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Native Hickories of Georgia I: History & Genetic Relationships

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A large group of native trees in the Southeast United States and within Georgia are hickories. They are difficult to identify to the species level because of the large variation in visible traits among the trees. This is the first of two publications dealing with this large native tree group. This publication deals with the history of the hickory family and genus, with insights into how all the Southeastern hickories are related.

The genus name for hickory is *Carya* and was first designated in 1818. "Carya" is from Greek "karya" meaning nut tree or kernel. (Grauke 2003) The word "hickory" is derived from the Powhatan Nation of Virginia's word for a crushed seed and water drink called "pokahichary." (Grauke 2003) Hickories also have had old genera names of *Juglans* and *Hicoria*. Common names for the genus as a whole have included caryer and hicorier derived from scientific names.

Family Matters

The walnut family *(Juglandaceae*), of which the hickory genus (*Carya*) is a member, has a somewhat confused and complex taxonomy. Depending upon how the family is divided or consolidated by different authors, the number of genera and species varies. Over the past 50 years, the number of genera and species have been cited as: 8 genera / ~60-65 species (Elias 1972); 7 genera / 59 species (Manning 1978); 8 genera / ~60 species (Manchester 1989); 9 genera / 60 species (Manos et.al. 2007); and, 9 genera / ~60 species (Xiang et.al. 2011). Whatever the precise count, the genus *Carya* – hickory is found within the walnut family.

Walnut family members grow primarily in low and mid latitudes of the Northern Hemisphere, but do extend southward to mountain areas of tropical America and Asia. (Elias 1972; Manos et.al. 2007; Xiang et.al. 2011) The walnut family is distributed in North, Central, and South America, West Indies, eastern Asia, Japan, Philippines, East Indies, Himalayas, southwestern Asia, & southeastern Europe to the Caucasus mountains. (Manning 1978) This family was more widespread around the globe before the Pleistocene Epoch (>2.58mya). Many large and diverse populations of walnut family members became extinct in the last 5 million years.

Taxonomic subdivisions within the walnut family help organize the genera and species. For the hickories (*Carya* spp.) within the family *Juglandaceae,* their subfamily is *Juglandoideae*, of the *Juglandeae* or *Hicoreae* tribe, *Caryinae* subtribe, and *Carya* genus. (Grauke 2003; Manchester 1989; Manning 1978; Manos & Stone 2001) This lineage has a fossil record dating from the Eocene (34-56mya). (Manchester 1989)

Family History

The *Juglandaceae* (walnut family) was a much more widespread and larger family than today. (Elias 1972) Precursors to what would become the walnut family can be found in the late Cretaceous (66-100mya) in the southeastern United States and Europe, demonstrating early connections across North Atlantic land bridges. (Grauke 2003; Manchester 1999) The walnut family subtribe *Carinae* or *Hicoreae* (including hickory precursors) arose from more primitive ancestors about 70mya. (Grauke 2003)

By the very early Tertiary (60-66mya) many walnut family genera and species were present. (Manchester 1989) The walnut family expanded its range and diversified quickly (primarily because of wind pollination evolution) in the Paleocene (56-66mya) in both North America and Europe, much later in Asia. (Manchester 1989) North America is the origin of the walnut family and of the hickories *(Carya* genus), with migration across both northern Atlantic and Pacific land bridges at various times. (Grauke 2003; Xiang et.al. 2004)

Hickory History

Primitive members of the walnut family *Carinae* subtribe covered North America and Eurasia during the Eocene (34-56mya). (Grauke 2003) *Carya* species first arose in North America at this time, spreading to Europe during the Oligocene (23-34mya) and to Eastern Asia from North America during the Miocene (5.3-23mya). (Manchester 1999)

Carya species have never been found in Cretaceous (before 66mya) fossils, but was abundant in the Tertiary (2.6-66mya). (Elias 1972) The earliest confirmed fossil record date for *Carya* is in western North America during the Eocene (34-56mya). (Xiang et.al. 2004) *Carya* fruits in the fossil record were first recorded in the late Eocene (34-41mya). *Carya* genus fruits were also found in lower Oligocene (23-28mya) fossils. (Grauke 2003) A variety of different *Carya* species fossils occur in North America and Eurasia beginning in the Oligocene (23-34mya) and onward to recent times. (Xiang et.al. 2004) Multiple *Carya* species were present across the western United States during the Tertiary (2.6-66mya). (Elias 1972)

Bust or Boom

Major expansion in North America of the genus occurred during the Tertiary Epoch (Oligocene (23-34mya) to Pliocene (2.6-5.3mya), exploding in species number and range during the Miocene (5.3-23mya) across Europe. (Manchester 1989; Manchester 1999; Xiang et.al. 2004) *Carya* species found in Eastern Asia and Eastern North America today, were found across the entirety of North America during the late Eocene (34-40mya) as shown in the fossil record. (Manchester 1999) *Carya* fossils are known from the Eocene (34-56mya) and Miocene (5.3-23mya) in Alaska, western and northwestern United States, New England, southeastern United States, Greenland, Iceland, Svalbard, central Europe, Russian Kamchatka, and China Shantung.

Carya became extinct in Europe after a great amount of successful speciation. The diversity of European *Carya* species were driven to extinction across the entire continent by ice age patterns and east-west mountain barriers to migration during the Pleistocene (2.6-5.3mya) and Holocene (<12,000 years ago). (Grauke 2003; Manchester 1999) During this same time period, *Carya* species also became extinct in western North America, while *Carya* species in eastern North America were greatly reduced. (Grauke 2003)

Recent Changes

Hickories in the Eastern United States were pushed southward multiple times by glacial events (2.6 mya to 14,000 years ago). Glacial refuges for many hickory upland species during the last glacial drift were concentrated in southern Mississippi, southern Alabama, and south-west Georgia. After the last glacial retreat, these hickory species returned to the Northern United States and Southern Canada by two primary pathways, one on the east side of the Appalachians and one up the Mississippi and Ohio river valleys. In *Carya* wetland and bottomland species, they expanded their range after glacial withdrawl from the upper Mississippi River valley refuges. (Bemmels et.al. 2019) Hickory species adapted to more mesic and wetter soil systems were able to persist closer to the ice sheets in this more northern refuge. (Bemmels et.al. 2019)

For example, bitternut hickory (*Carya cordiformis*) found on mesic sites and in bottomlands, and shagbark hickory (*Carya ovata*) found on dry sites and in uplands were examined for expansion following the last retreating glacier. Bitternut hickory's glacial refuge was centered near the southern tip of Illinois and southern Missouri, whereas shagbark hickory's glacial refuge was concentrated in the states of Mississippi and Alabama (Bemmels et.al. 2019) Hickory species which have overlapping ranges today may have followed radically different expansion pathways after the last glacial period. (Bemmels et.al. 2019)

Northbound Sprint

After the last glacial drift, *Carya* species, having been concentrated in refuges began migrating northward. *Carya* advanced northward from 34° N beginning about 16,000 years ago, reaching its current limit of 45° N by 8,000 years ago. *Carya* moved an average of 1,161 feet northward per year. (Grauke 2003) The fastest period of movement northward for *Carya* was between 12,000 and 14,000 years ago. (Grauke 2003)

Carya has evolved along a different path than other walnut family members, and is the most advanced genus in the family. (Manning 1978) *Carya* developed many specialized traits for helping mitigate ecological constraints. *Carya* developed an advanced secondary xylem with distinct ring porosity and rounded, thick-walled vessels. (Elias 1972) *Carya* also developed the most specialized flowers in its family. (Elias 1972)

The *Carya* Genus

Multiple authors disagree on the exact number of species in the *Carya* genus and how to divide or organize the genus's species into associated close groups. (Grauke 2003) Total *Carya* species numbers vary by author, but include about 18 (13-19) ranging from Eastern North America to Southern Mexico and East Asia. More accurately: Eastern United States has 11-12 species (2-4 species extend into Canada); Mexico has 4 species (3 species overlap with the Eastern United States species); and, Asia (China, southeast Asia, & India) has 5-6 species. (Elias 1972; Grauke 2003; Manning 1978) The Southeastern United States is the diversity center for the genus.

Other papers lists the *Carya* genera in Eastern United States and Mexico having 12-14 species. (Hardin & Stone 1984), or listing *Carya* species in Eastern North America as 16. (Xiang et.al. 2004) Figure 1 lists the native and naturalized *Carya* species of Georgia and surrounding states to be used here, using scientific name, historic scientific names now discarded or consolidated (i.e. synonyms), common names, and the genus section within which they have been placed.

Sectional Division

Major divisions within the *Carya* genus are made between related species. Each sub-grouping (called a genus section) could almost be considered a genera by itself, but there are 1-2 intermediate species which tie the entire genus together. Figure 2 provides species found in each *Carya* genus section in the southeastern United States and a count of species across eastern North America. (Manning 1978)

All the *Carya* genus sections include: (Elias 1972; Grauke 2003; Manning 1978)

Section A (*Apocarya*) – pecan hickories.
4-5 species in Eastern United States; 1 species in Mexico;
& 2-3 species in Eastern Asia.

Section C (*Carya*) – true hickories.
7-10 species in Southeastern United States.

Section R (*Rhamphocarya*) – Asian hickories.
1 species in East Asia.
Note: some authors place Section R in a new genus *Annamocarya.*

Section S (*Sinocarya*) – Southeast Asian hickories.
5 species in southeastern & eastern Asia.

Cross-sectional hybrids between species in section *Apocarya* and section *Carya* exist. (Stone et.al. 1969) The Asiatic *Carya* species will not be discussed here.

Section *Apocarya* – has ~8 species scattered in the eastern United States, Mexico and Asia. (Elias 1972) The *Carya* genus section *Apocarya* (pecan hickories) are all diploid (n=16) (Grauke 2003; Manos & Stone 2001; Stone et.al. 1969) The *Apocarya* section species have 7-17 serrate, usually falcate shaped leaflets, held on alternate odd-pinnate compound leaves, with 4-6 valvate (not overlapping) terminal bud scales on a bud which swells little in Spring, a husk with sutures frequently winged, and air space gaps within the nut. (Elias 1972; Grauke 2003; Manos & Stone 2001) Section *Apocarya* species tend to develop staminate catkins (male flowers) from lateral buds of the preceding season's shoots. (Manos & Stone 2001) Figure 3 helps differentiate between *Carya* genus sections in eight ways plus general habitat. (Grauke 2003; Manning 1978)

Section *Carya* – the true hickories contain both diploids (n=16) (*i.e. Carya carolinae-septentrionalis, Carya myristiciformis, Carya laciniosa, Carya ovata*) and tetraploids (n=32) (*i.e. Carya floridana, Carya glabra, Carya ovalis, Carya pallida, Carya texana, Carya tomentosa*) species. (Manos & Stone 2001; Stone et.al. 1969) The *Carya* section species tend to have 3-9 serrate, usually not falcate shaped leaflets, held on alternate odd-pinnate compound leaves, terminal buds which swell greatly in Spring and have imbricate (overlapping) bud scales with 6-12 scales, and husks with unwinged suture lines. (Grauke 2003; Manos & Stone 2001) Section *Carya* develop staminate catkins (male flowers) in a narrow band at the base of leafy shoots. Section *Carya* species have nut shells which are thick with nut cross-sections which are solid without gaps. (Manos & Stone 2001)

Genetics

Chromosome numbers among *Carya* species can help determine ease of hybridization, response to environmental constraints and differing morphological features. For example, hickory seed oils differ by species, genus section, and by ploidy level (chromosome number). (Stone 1964) The base number of chromosomes for the walnut family is n=16, with the *Carya* genus having diploids n=16 and tetraploids n=32 species. (Manos & Stone 2001) Six species of *Carya* are tetraploids (n=32). (Manning 1978; Stone 1964) The tetraploids only occur within the *Carya* section (Section C).

The *Carya* genus has numerous interspecific hybrids, some of which are very common where the two parent populations overlap. Figure 4 is a list of known hickory hybrids (both named and unnamed), their general range where they can be found, and the genus section to which they belong. Figure 5 shows a hybrid web of interconnections for hickories. (Grauke 2003; Hardin & Stone 1984) There are also a number of hickory varieties and forms which have been named over many years, some potentially hybrids, but most representing simple unique morphological populations. (Elias 1972; Grauke 2003; Sargent 1918) For all the hickories, there have been many scientific names given for populations with minor inter-gradations of fruit shape & size, trichome forms, and foliage attributes. Most of these names have not been accepted and have been combined within standard species groups.

A Common Problem

There are many common names for hickory species. The most commonly used are listed by various authors in the species descriptions. For the native hickories of Georgia there are at least 36 common names used multiple times for different hickory species. In addition, there are 22 common names used only once for a hickory species. Regional and local names for various hickory species can be confusing.

For example, the common name "pignut" hickory is used in 13 different ways to describe 6 different hickory species. On the other hand, the name "shellbark" is used in 6 different combinations to describe a single hickory species, and is not used for any other hickory. Figure 6. Common names should be avoided when accurately describing hickory species. The single scientific name is the best way to describe which hickory being described.

Hickory Values & Use

Hickory (*Carya*) seeds are high in protein, high in fat, and low in carbohydrate as a food item. Hickory nuts are nutrient dense and large, well adapted for animal (primarily rodent) dispersal. (Manchester 1989; Manos & Stone 2001) Earliest human use of *Carya* species (dominated by *Carya illinoinensis* – pecan) were found in the Early Archaic (8,700-8,900 years ago), primarily for seed consumption, cooking oil, drinks, and medicine. (Grauke 2003) Hickory nuts have seen strong use for both human and animal food consumption.

Hickories are known for valuable wood qualities. Hickory has strong, tough, shock resistant wood effectively used for tool handles, golf clubs, skis, baseball bats, longbows, tennis rackets, cabinets, furniture parts, and floors for gymnasiums, roller skating rinks and ballrooms. Production of hickory lumber is difficult, as tree form is usually poor with many defects. (Grauke 2003) Hickory wood is extensively used for chips, sawdust, and

small chunks to smoke meats and cheese, with larger pieces used as high-grade fuelwood and charcoal. (Grauke 2003)

Commercial use of hickories have included wood products, fruit, and shade trees. For example, pecan (*Carya illinoinensis*) is the most important tree nut native to North America (naturalized in Georgia). Because of foliage and fruit litter, many hickories are not used widely for shade and ornamental trees. Selection of hickory species and individual trees for propagation and planting are almost always concentrated around nut attributes and not on ornamental landscape use. (Grauke 2003) *Carya cordiformis* (bitternut hickory), *Carya glabra* (pignut hickory), and *Carya ovata* (shagbark hickory) are grown in central Europe for timber.

Special Considerations – Nutmeg Hickory

Carya myristiciformis (nutmeg hickory) is listed here as a native tree of Georgia. Although not recently identified by field or herbarium samples, both the associated forest types and habitats which support nutmeg hickory elsewhere are present in Georgia. One source shows only one sample ever collected in Georgia, and another source shows five different sample locations, but away from typical nutmeg hickory sites.

Carya myristiciformis (nutmeg hickory) has features and growth forms representing both *Apocarya* and *Carya* sections of the *Carya* genus. Nutmeg hickory has valvate (non-overlapping) terminal bud scales and a husk with prominent wings along the sutures as in the *Apocarya* section species. Nutmeg hickory also has a small number of leaflets and a thick nut shell without internal cavities as in a *Carya* section species. (Grauke 2003) One of the earliest reviews stated *Carya myristiciformis* is in the *Apocarya* section, but helps connect the two sections of the genus. Without this species bridging between the two sections, these sections of the genus *Carya* should probably have been elevated as two separate genera. (Sargent 1918)

Belongings

There is debate about where to place nutmeg hickory. There is much support for placing this hickory in either *Apocarya* or *Carya* sections. There is a tendency for older literature to place it within the *Apocarya* section. (Hardin & Stone 1984; Manning 1978; Sargent 1918; Stone et.al. 1969) More recent reviews have placed nutmeg hickory in the *Carya* section. (Grauke 2003; Manos & Stone 2001) Note there is a spelling error or alternative spelling for this species: *Carya myristiciformis* is usually considered the correct spelling and *Carya myristicaeformis* is considered the incorrect spelling. (Elias 1972)

Besides showing key features of both genus sections, nutmeg hickory is most closely related to water hickory *(Carya aquatica)* which is in the *Apocarya.* The closeness of species ties is supported by micro leaf surfaces and seed oil content features. (Hardin & Stone 1984) Both of these closely related species act as links between the two *Carya* genus sections, and as the core foundation of the genus center in Eastern North America. (Elias 1972)

Close Relatives

Figure 7 and Figure 8 provide two limited views of hickory species relationships to each other. (Manos & Stone 2001; Manos et.al. 2007) Both *Carya cordiformis* (bitternut hickory) and *Carya illinoinensis* (pecan)

are always tied closely together, and *Carya myristiciformis* (nutmeg hickory) represents an intermediate between hickory sections. Figure 9 represents a much broader examination of the closeness between hickory species based upon nut oil content similarities. (Stone et.al. 1969)

Considering the connections between *Carya* genus sections and among species, several close relationships emerge among southeastern United States species. Bitternut hickory – *Carya cordiformis* and pecan – *Carya illinoinensis* within section *Apocarya* are each unique enough from other species in the section and genus to be given section rank. (Stone et.al. 1969) These diploid species represent an important division in the *Carya* genus. Shagbark hickory – *Carya ovata,* shellbark hickory – *Carya laciniosa,* and southern shagbark hickory – *Carya carolinae-septentrionalis* diploids represent a second related division among the *Carya* genus. Nutmeg hickory – *Carya myristiciformis* and water hickory – *Carya aquatica* represent a core group of diploids species linking the two sections of the genus.

Red hickory – *Carya ovalis,* a tetraploid, represents a single species comprising a third division of the genus closely related to the *Apocarya* section even though belonging in the *Carya* section. Scrub hickory – *Carya floridana* and black hickory – *Carya texana* tetraploids, although widely separated in their native ranges represent glacial refuge relic groups. Mockernut hickory – *Carya tomentosa,* sand hickory – *Carya pallida,* and pignut hickory – *Carya glabra* tetraploids represent the last division of similarities and relatedness among the *Carya* section of the *Carya* genus. (Stone et.al. 1969)

ID Problems

There is great confusion in identifying and differentiating *Carya glabra* (pignut hickory) and *Carya ovalis* (red hickory), as many traits are similar and their ranges greatly overlap. These two hickory species specifically, plus other closely related hickory species like black and scrub hickories, generate a multi-species complex where their ranges overlap. Red hickory (*Carya ovalis* – a *Carya* section tetraploid) is closely linked with the *Apocarya* section and may have led to the rest of the tetraploid *Carya* section species. (Stone et.al. 1969)

Conclusions

Native and naturalized hickories in Georgia represent a great ecological heritage covering every county in the State. Hickories are relatively new in geologic time and still quite diverse after the last ice ages. Unfortunately, hickeries through speciation, migration, glacial refudges, and overlapping ranges have generated a diverse genetic soup which has produced a wide variety of characteristics among all the hickory species and large number of hybrids. The second publication in this set provides individual species descriptions and identification characters.

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Scientific Name (Scientific Name Synonyms)	Common Name	Genus Section
Carya aquatica	**water hickory**	**A**
Carya aquatica var. australis		
Carya integrifolia		
Carya carolinae-septentrionalis	**southern shagbark hickory**	**C**
Carya ovata var. australis		
Carya ovata var. carolinae-septentrionalis		
Carya cordiformis	**bitternut hickory**	**A**
Carya amara		
Carya cordiformis var. latifolia		
Carya floridana **	**scrub hickory**	**C**
Carya glabra	**pignut hickory**	**C**
Carya amara var. porcina		
Carya glabra var. hirsuta		
Carya glabra var. megacarpa		
Carya leiodermis		
Carya megacarpa		
Carya magnifloridana		
Carya microcarpa		
Carya ovalis var. hirsuta		
Carya X ovalis var. hirsuta		
Carya pecan		
Carya porcina		
Carya illinoinensis	**pecan**	**A**
Carya angustifolia		
Carya diguetii		
Carya illinoensis		
Carya olivaeformis		
Carya oliviformis		
Carya pecan		
Carya tetraptera		
Carya laciniosa	**shellbark hickory**	**C**
Carya sulcata		
Carya myristiciformis	**nutmeg hickory**	**~AC**
Carya fernowiana		

**** = non-native to Georgia**

Figure 1: Native and naturalized hickory species of Georgia and surrounding states with past associated scientific names, common names, and genus section. (contiued)

Not included are historic genus names *Hicoria* and *Juglans.*

(A = *Apocarya* -- pecan hickories; C = Carya -- true hickories).

Scientific Name (Scientific Name Synonyms)	Common Name	Genus Section
Carya ovalis	**red hickory**	**C**
Carya alba var. ovalis		
Carya borealis		
Carya glabra var. odorata		
Carya leiodermis		
Carya microcarpa		
Carya ovalis var. hirsuta		
Carya ovalis var. mollis		
Carya ovalis var. obcordata		
Carya ovalis var. obovalis		
Carya ovalis var. odorata		
Carya X ovalis var. odorata		
Carya ovata	**shagbark hickory**	**C**
Carya alba		
Carya australis		
Carya carolinae-septentrionalis		
Carya ovata var. fraxinifolia		
Carya ovata var. nuttallii		
Carya ovata var. pubescens		
Carya pallida	**sand hickory**	**C**
Carya texana **	**black hickory**	**C**
Carya arkansana		
Carya buckleyi		
Carya buckleyi var. arkansana		
Carya glabra var. villosa		
Carya texana var. arkansana		
Carya texana var. villosa		
Carya villosa		
Carya tomentosa	**mockernut hickory**	**C**
Carya alba		
Carya tomentosa var. subcoriacea		

**** = non-native to Georgia**

Figure 1: Native and naturalized hickory species of Georgia and surrounding states with past associated scientific names, common names, and genus section. (contiued)

Not included are historic genus names *Hicoria* and *Juglans.*

(A = *Apocarya* -- pecan hickories; C = Carya -- true hickories).

Carya Section:

(8 species – Eastern US)

Carya floridana
Carya glabra
- ***Carya glabra var. hirsuta***
- ***Carya glabra var. megacarpa***

Carya laciniosa
Carya ovalis
- ***Carya ovalis var. mollis***

Carya ovata
- ***Carya ovata var. australis***
- ***Carya ovata var. pubescens***

Carya pallida
Carya texana
- ***Carya texana var. villosa***

Carya tomentosa

Apocarya Section:

(5 species – Eastern NA;
4 species US; 1 species Mexico)

***Carya* aquatica**
***Carya* cordiformis**
***Carya* illinoinensis**
Carya* myristiciformis

(* = has been listed in either section of *Carya* genus)

Figure 2: *Carya* genus sections In southeastern United States (Manning 1978)

Carya Section (true hickories)

(tends to cooler dryer sites)

1. 6-12 imbricate (overlapping) bud scales
2. buds swell & enlarge in Spring
3. 3-9 serrated leaflets not falcate shaped
4. husk 4 valved (4 sutures)
5. husk with no wings along sutures
6. nut shell thick & solid inside
7. diploids n=16 & tetraploids n=32
8. wood relatively strong & more dense

Apocarya Section (pecan hickories)

(tends to warmer wetter sites)

1. 4-6 valvate bud scales not overlapping
2. buds buds remain nearly same size in Spring
3. 7-17 serrated leaflets usually falcate in shape
4. husk usually 4 valved (possible 3-6 sutures)
5. husk winged along sutures
6. nut shell thin with internal air gaps
7. diploids n=16 only
8. wood relative weak & less dense

Figure 3: Differentiating between *Carya* genus sections of the Southeast. (Grauke 2003; Manning 1978)

Named Hybrids:

hybrid name	hybrid parents	hybrid location range	section
Carya X brownii	(cordiformis x illinoinensis)	lower MS & OH valleys	A
Carya X collina	(texana x tomentosa)	AR MO	C
Carya X demareei	(cordiformis x ovalis)	AR KY	AC
Carya X dunbarii	(laciniosa x ovata)	NY	C
Carya X laneyi	(cordiformis x ovata)	PA & NORTH	AC
Carya X lecontei	(aquatica x illinoinensis)	TX to IL MS valley SC	A
Carya X ludoviciana	(aquatica x texana)	LA	AC
Carya X nussbaumeri	(illinoinensis x laciniosa)	KY to IA MO to IN	AC
Carya X schneckii	(illinoinensis x tomentosa)	IA IL	AC

Known but Unnamed Hybrids:

	hybrid parents	section
Carya X _____	(cordifomis x tomentosa)	AC
Carya X _____	(glabra x ovalis) **	C
Carya X _____	(illinoinensis x myristicaeformis)	AC
Carya X _____	(illinoinensIs x ovata)	AC
Carya X _____	(ovata x tomentosa)	C
Carya X _____	(glabra x tomentosa)	C
Carya X _____	(ovalis x tomentosa)	C
Carya X _____	(carolinae-septentrionalis x ovata)	C

** = very common hybrid in field

Figure 4: List of known hybrids (both named and unnamed) among the native / naturaized hickory species of Georgia, their hybrid range, and their genus section(s). Anywhere species ranges overlap, hybrids are possible.
(A = *Apocarya* -- pecan hickories; C = *Carya* -- true hickories).

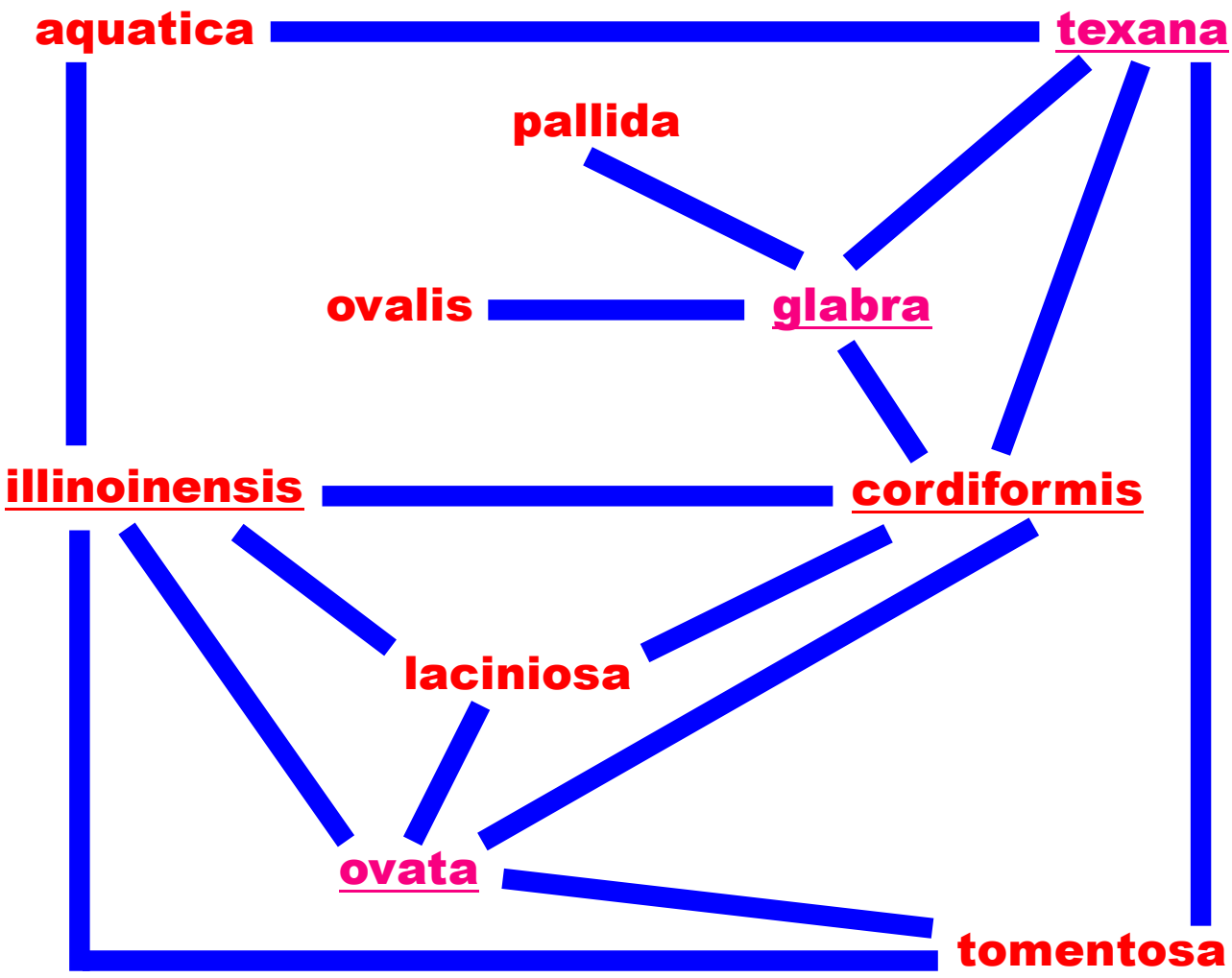

Figure 5: Hickory Hybrid Web: Hybrid species lines cited in literature -- distances between species in diagram are NOT related to gentic similarities, but are simply showing parents of hybrids.

Primary hubs are *Carya cordiformis* and *Carya illinoensis*.
Secondary hubs are *Carya glabra, Carya ovata* and *Carya texana.*

hickory common name	number of different common names	number of different species
pignut	13	6
shagbark	6	4
shellbark	6	1
swamp	4	4
pecan	4	2
water	3	2

Figure 6: Number of common names used across native hickories of Georgia species, and number of different hickory species identified by the same common name.

For example: Native hickories of Georgia have at least 36 common names used multiple times for different hickory species, as well as 22 common names used only once for a species.

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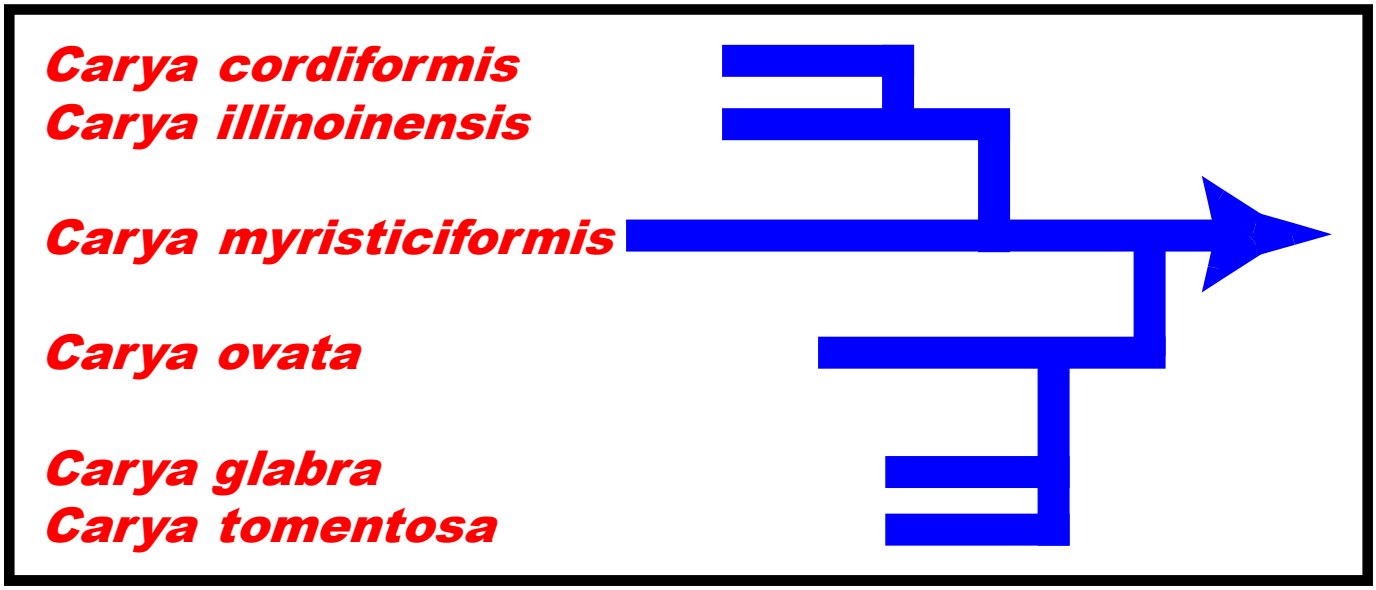

Figure 7: Relationship between selected *Carya* species based upon genetic markers.
(derived from Manos & Stone 2001)

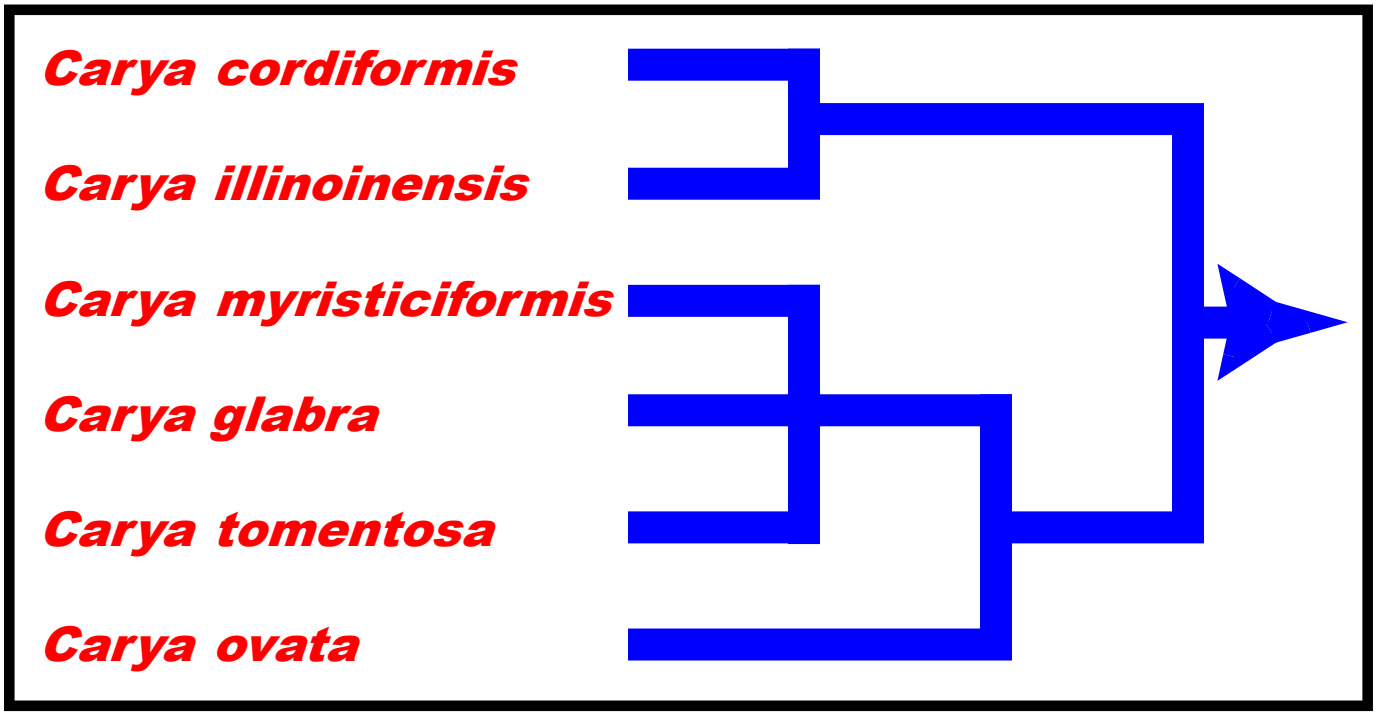

Figure 8: Relationship between selected *Carya* species based upon morphology and DNA data.
(derived from Manos et.al. 2007)

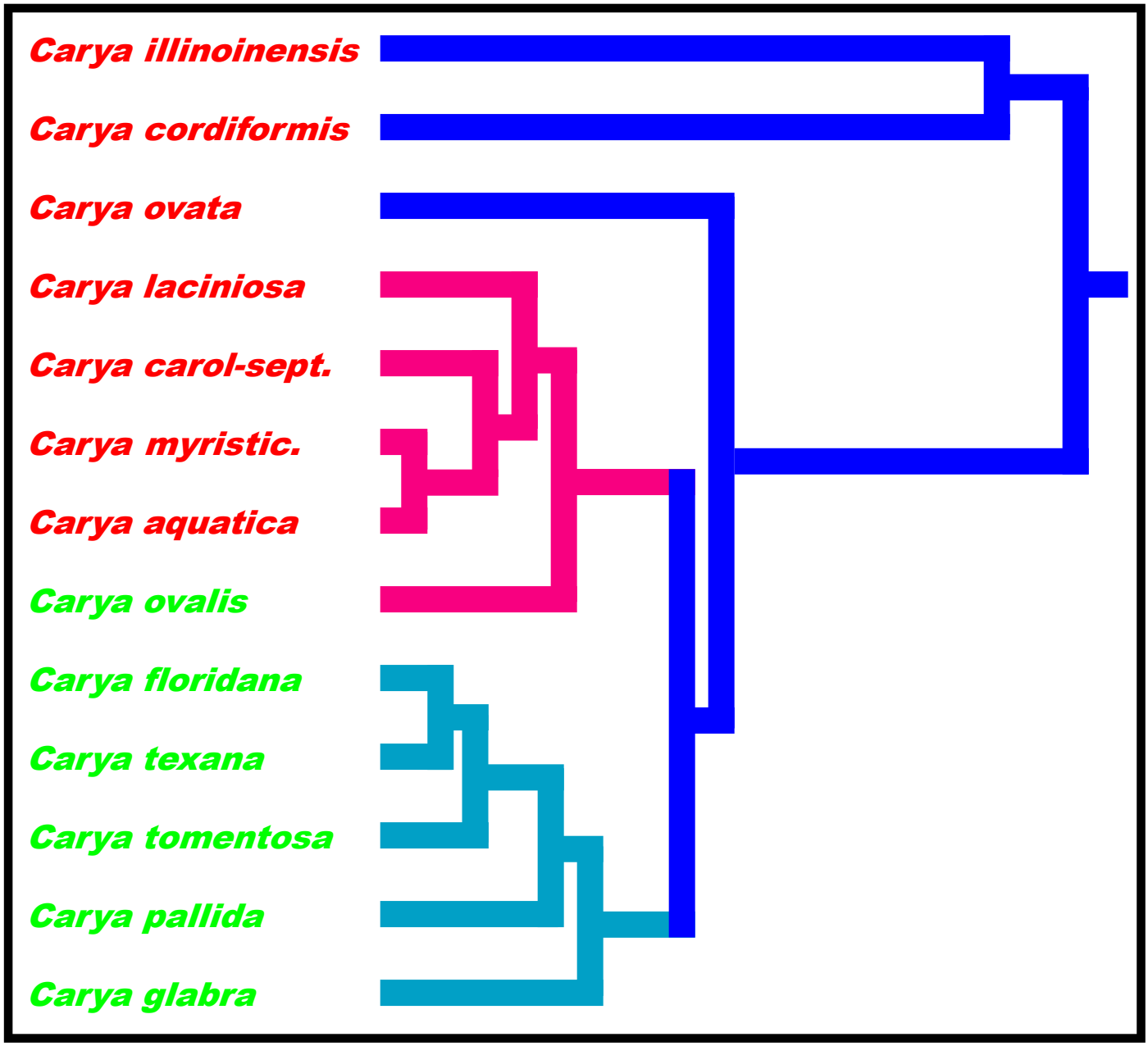

Figure 9: Relationship between selected *Carya* species based upon nut oil content similarity.
(green species are tetraploids & red species are diploids)
(derived from Stone et.al. 1969)