Molecular Systematics & Ethnobotany Case Study: Breadfruit

Thanks to Tim Motley & Nyree Zerega for pictures and information.

- Hawaii, California, Bering Straight
- “Bounty-hunting”
- “Pandora’s Box”
- Breadfruit
- Molecular systematics

I. Circumstances Leading to the Mutiny on the Bounty

William Bligh

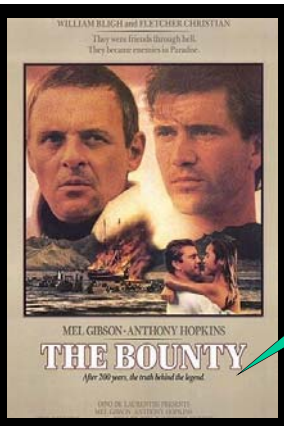
-James Cook’s sailing master (3rd Voyage; 1776)

-Captain, HMS *Bounty* (1787-1789)

HMS *Bounty*

George III (reign: 1760-1820)
portrait by Allan Ramsay, 1762

Mutiny on the Bounty, 1789



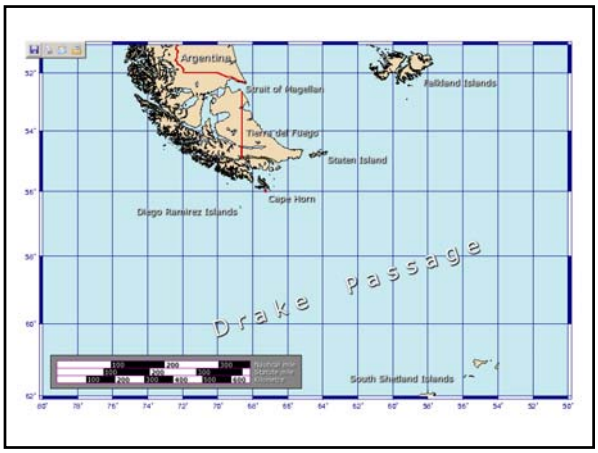
…the truth behind the legend.

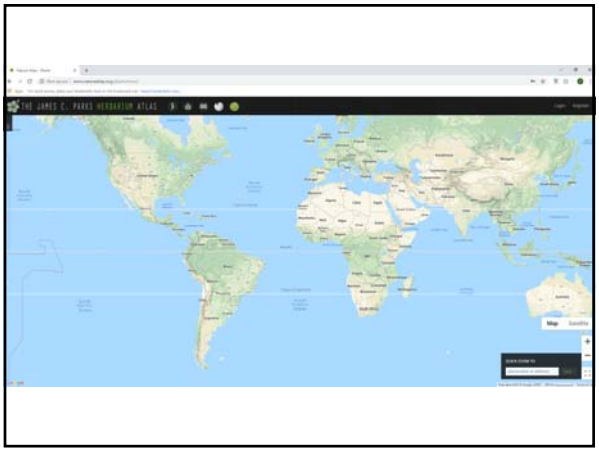
The voyage of the HMS Bounty, 1787-1789

-23 Dec 1787, departed for Tahiti

Mission: To collect breadfruit for West Indies.

Crew:
Bligh (Captain)
Fletcher Christian (Master's Mate)
2 Civilian botanists
42 other s


Argentina
Strait of Magellan
Falkland Islands
Tierra del Fuego
Staten Island
Cape Horn
Diego Ramirez Islands
Drake Passage
South Shetland Islands




Cape Town
Paarl
Stellenbosch
Cape of Good Hope
Cape Aguhlas

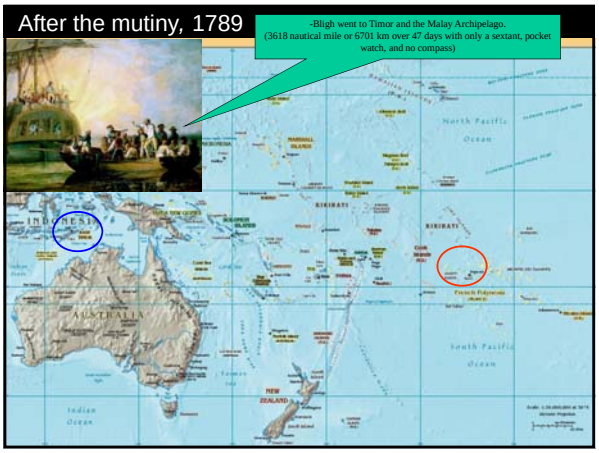
The voyage of the HMS Bounty, 1787-1789

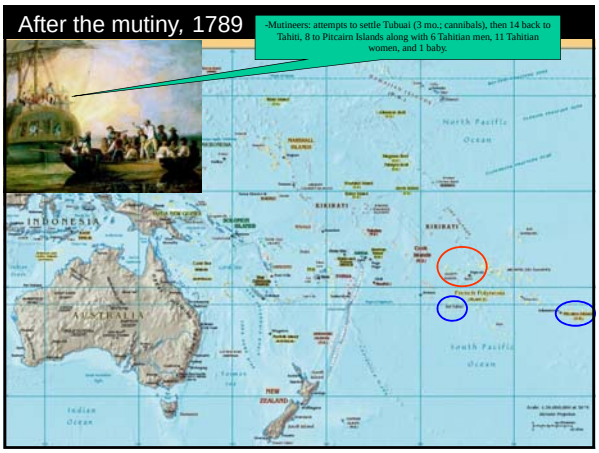
-28 Oct 1788, reached Tahiti

5 mos. collecting & preparing
1015 breadfruit trees.

-4 Apr 1789; set sail for West Indies

After the mutiny, 1789




After the mutiny, 1789
-Mutineers: attempts to settle Tubuai (3 mo.; cannibals), then 14 back to Tahiti, 8 to Pitcairn Islands along with 6 Tahitian men, 11 Tahitian women, and 1 baby.
North Pacific Ocean
INDONESIA
AUSTRALIA
KIRIBATI
South Pacific Ocean
Indian Ocean
NEW ZEALAND


Why the mutiny?


Why the mutiny?

After the mutiny

HMS *Pandora*

Pandora by John W. Waterhouse, 1896

-14 mutineers in Tahiti caught, held in "Pandora's Box"

Pandora (G.) =
•Ca. 8th Century BCE
•first woman, a gift from Zeuss & other gods
•She comes bearing another gift – a mysterious jar.
•She gives into temptation & The rest is history (or myth).

Pandara engraving based on painting by FS Church

After the mutiny

HMS *Pandora*

Pandora by John W. Waterhouse, 1896

-14 mutineers in Tahiti caught, held in "Pandora's Box"

-Return (1791): Great Barrier Reef, 4 prisoners and 31 crew lost, Timor refuge.

-Britain (1792): 10 surviving "mutineers" tried.

Pandara engraving based on painting by FS Church

After the mutiny

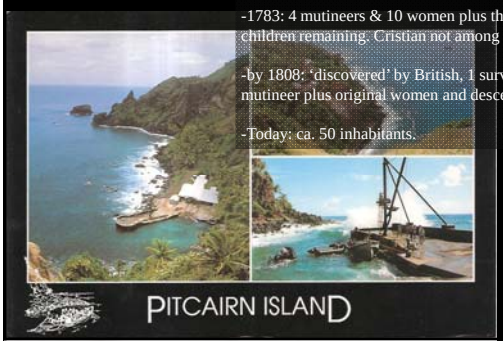
Pitcairn Islands

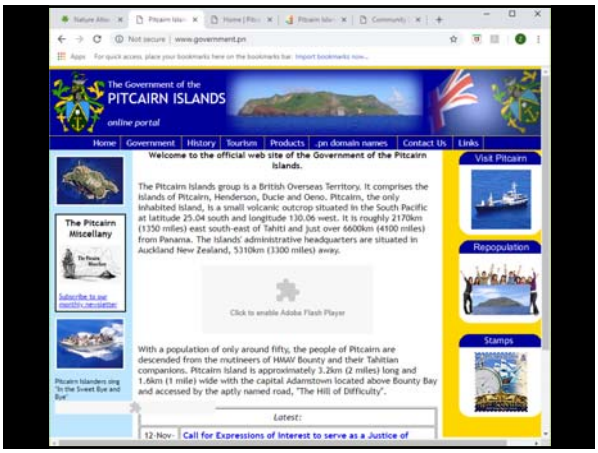
-1789: 8 mutineers, 6 Tahitian men, 11 women and 1 baby.

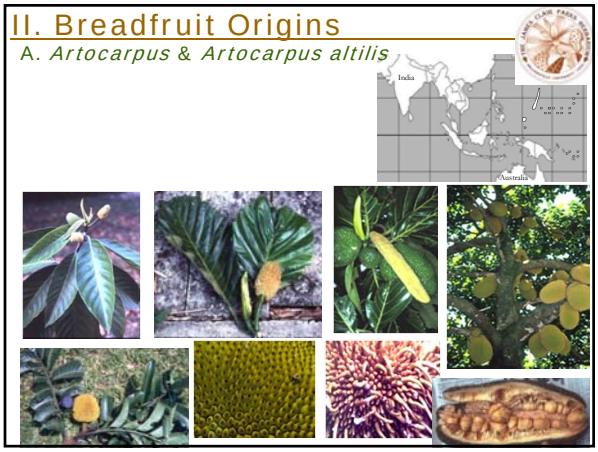
-1783: 4 mutineers & 10 women plus their children remaining. Cristian not among them.

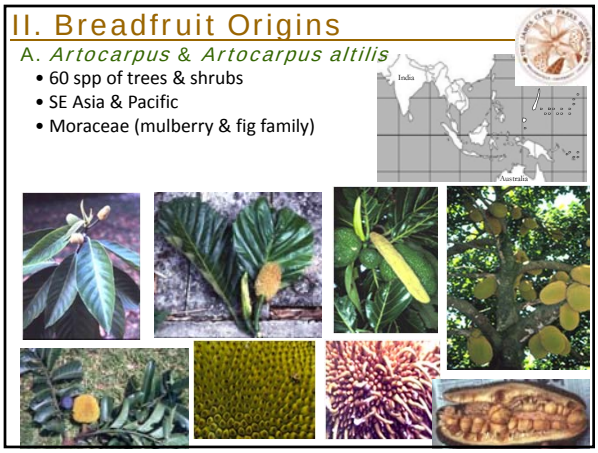
-by 1808: 'discovered' by British, 1 surviving mutineer plus original women and descendants.

-Today: ca. 50 inhabitants.




The Government of the
PITCAIRN ISLANDS
online portal
Home | Government | History | Tourism | Products | .pn domain names | Contact Us | Links
Welcome to the official web site of the Government of the Pitcairn Islands.
The Pitcairn Islands group is a British Overseas Territory. It comprises the islands of Pitcairn, Henderson, Ducie and Oeno. Pitcairn, the only inhabited island, is a small volcanic outcrop situated in the South Pacific at latitude 25.04 south and longitude 130.06 west. It is roughly 2170km (1350 miles) east south-east of Tahiti and just over 6600km (4100 miles) from Panama. The islands' administrative headquarters are situated in Auckland New Zealand, 5310km (3300 miles) away.
With a population of only around fifty, the people of Pitcairn are descended from the mutineers of HMAV Bounty and their Tahitian companions. Pitcairn Island is approximately 3.2km (2 miles) long and 1.6km (1 mile) wide with the capital Adamstown located above Bounty Bay and accessed by the aptly named road, 'The Hill of Difficulty'.
The Pitcairn Miscellany
Visit Pitcairn
Repopulation
Stamps
Latest:
12-Nov- Call for Expressions of Interest to serve as a Justice of

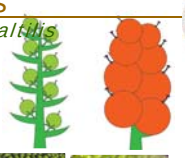

II. Breadfruit Origins
A. Artocarpus & Artocarpus altilis
India
Australia

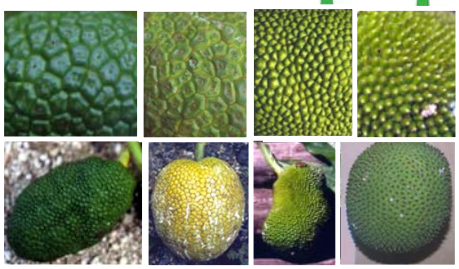

II. Breadfruit Origins
A. Artocarpus & Artocarpus altilis
• 60 spp of trees & shrubs
• SE Asia & Pacific
• Moraceae (mulberry & fig family)
India
Australia

II. Breadfruit Origins

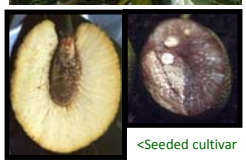
A. *Artocarpus* & *Artocarpus altilis*

- Produce large, multiple fruits
- Source of breadfruit & jackfruit



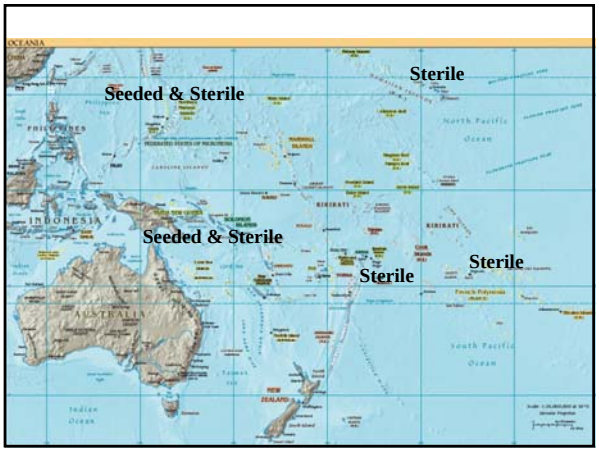


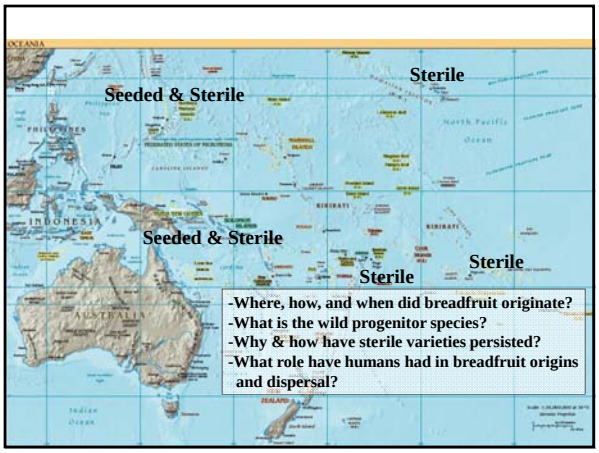
- Starch staple of Pacific islands, millennia.
- Humans selected for sterile (seedless) cultivars.
- Sterile throughout much of range.
- Classic example of crop species that evolved & spread with humans.



<Seeded cultivar

Seeded wild species >





II. Breadfruit Origins

B. 3 Prior Hypotheses

1. Morphological Evidence:
   - similarity to two other species

A. mariannensis (dugdug) | *A. altilis* (breadfruit) | *A. camansi* (breadnut)

II. Breadfruit Origins

B. 3 Prior Hypotheses

1. Morphological Evidence:
   - Fruit shape & texture is variable in *A. altilis* and intermediate between the other two.

A. mariannensis (dugdug) | *A. altilis* (breadfruit) | *A. camansi* (breadnut)

II. Breadfruit Origins

B. 3 Prior Hypotheses

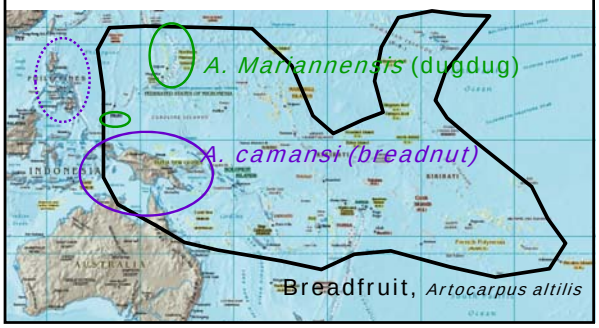
1. Morphological Evidence:
   - Leaves are variable, but suggest contributions from both

A. mariannensis (dugdug) | *A. altilis* (breadfruit) | *A. camansi* (breadnut)

II. Breadfruit Origins

B. 3 Prior Hypotheses

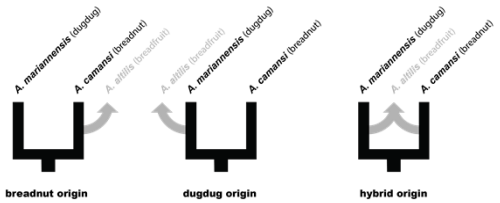
2. Biogeographical Evidence:
   - Overlapping distributions



II. Breadfruit Origins

B. 3 Prior Hypotheses

3. 3 Prior Hypotheses:



II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used
   a. Phylogeny reconstruction within *Artocarpus*
      1) Phylogenetic (cladistic) inference can be done with either molecular or morphological characters.

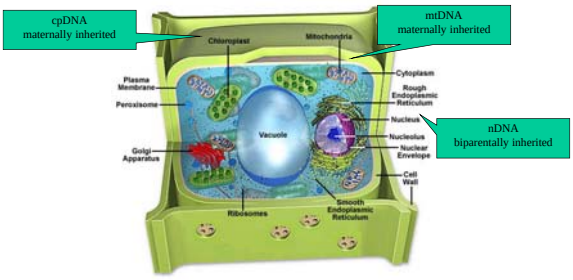
II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used

a. Phylogeny reconstruction within *Artocarpus*

2) Plants have 3 genomic sources of molecular data



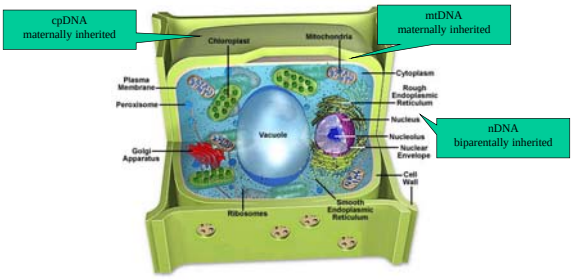
II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used

a. Phylogeny reconstruction within *Artocarpus*

3) Zerega et al. used two genes: ITS and trnLF



II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used

a. Phylogeny reconstruction within *Artocarpus*

4) PCR & DNA sequencing
allows selective amplification and determining
the nucleotide sequence of a small region of DNA

nuclear ribosomal DNA locus

II. Breadfruit Origins

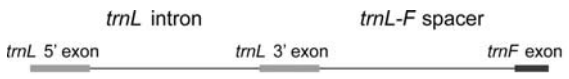
C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used

a. Phylogeny reconstruction within *Artocarpus*

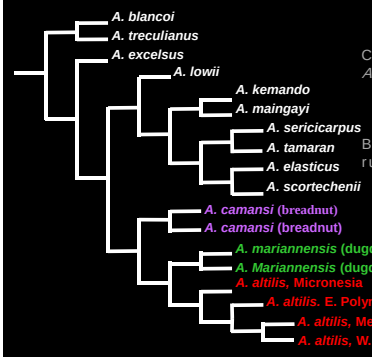
4) PCR & DNA sequencing

allows selective amplification and determining the nucleotide sequence of a small region of DNA



trnL – trnF region

Portion of most parsimonious cladogram



Conclusions:

A. camansi & *A. mariannsis* are BF's closest relatives. BF may be derived from *A. mariannensis*.

But Hybrid Hyp. can't be ruled out cladistically.

1) Cladograms only resolve phylogeny, and not tokogeny.
2) Although ITS or trnLF may be from *A. mariannensis*, other genes may be from *A. camansi*
3) >200 cultivars exist for A. altilis

Problems with 1- to few-gene approach when dealing with hybrid hypothesis (for nuclear genes):

A. mariannensis
dugdug
AABB

X

A. camansi
breadnut
aabb

⬇

Arto. altilis
AaBb

F1 Hybrids are expected to have genetic markers of both species ("additivity") for nuclear genes.

Problems with 1- to few-gene approach when dealing with hybrid hypothesis (for nuclear genes):

A. mariannensis
dugdug
AABB

X

A. camansi
breadnut
aabb

Arto. altilis
AaBb

Arto. altilis
AaBb

X

Arto. altilis
AaBb

Problems with 1- to few-gene approach when dealing with hybrid hypothesis (for nuclear genes):

A. mariannensis
dugdug
AABB

X

A. camansi
breadnut
aabb

Arto. altilis
AaBb

Sex in hybrid species would thoroughly mix alleles.

Arto. altilis
AaBb

X

Arto. altilis
AaBb

Arto. altilis,
AABB
AABb
AAbb
AaBB
AaBb
Aabb
aaBB
aaBb
aabb

Cladogram derived from gene A using either of these plants as *A. altilis* representative would show dugdug as sister.

Cladogram derived from gene A using this plant as an *A. altilis* representative would show breadnut as sister.

Problems with cpDNA or mtDNA approach when dealing with hybrid hypothesis:

A. mariannensis
dugdug
cpHaplotype M

X

A. camansi
breadnut
cpHaplotype C

Arto. altilis
cpHaplotype M or C, depending who the mother was

Problems with cpDNA or mtDNA approach when dealing with hybrid hypothesis:

A. mariannensis
dugdug
cpHaplotype M

X

A. camansi
breadnut
cpHaplotype C

⬇

Arto. altilis
cpHaplotype M or C, depending who the mother was

II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

1. Methods Used

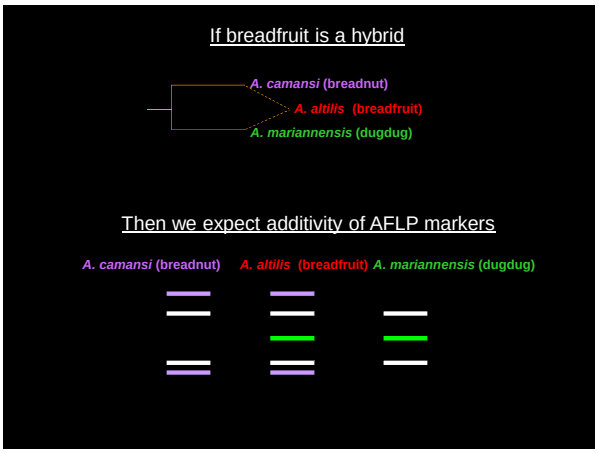
b. AFLP Analysis in *Artocarpus marianensis, A. altilis* and *A. camansi*.

1) Key points to AFLP approach for testing hybrid hypothesis
   - sampling of many individuals within species and cultivars .
   - Rapid, genome-wide rather than 1 or two genes.
   - Look for additivity of *A. marianensis* and *A. camansi* markers in *A. altilis*.

2) Method Summary
   - Extract DNA from many different trees for each species
   - Cut-up into tiny piecies using restriction enzymes that cut at precise sequence motifs
   - PCR-amplify all fragments
   - Electrophoresis to visualize fragments

Amplified Fragment Length Polymorphisms (AFLPs)

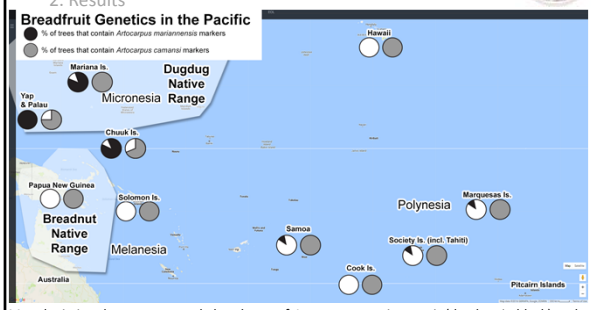
(DNA fingerprinting)



II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

2. Results

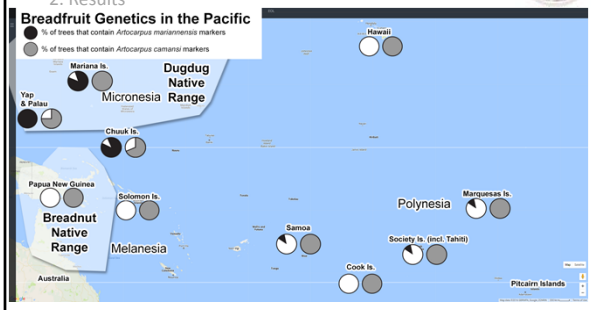


Map depicting the presence and abundance of *Artocarpus mariannensis* (dugdug, in black) and *A. camansi* (breadnut, in grey) AFLP genetic markers in breadfruit cultivars throughout Oceania (incl. Micronesia, Melanesia, and Polynesia).

II. Breadfruit Origins

C. Hypothesis Testing (Zerega et al. 2005)

2. Results

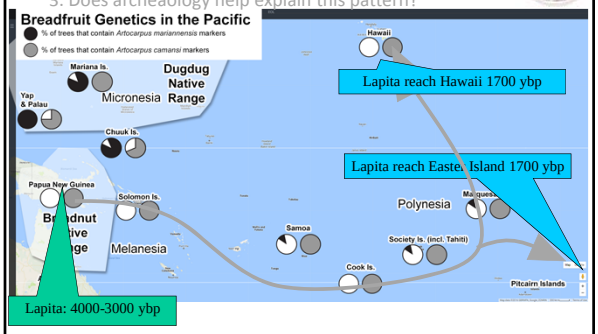


-breadnut markers found in all breadfruit, dugdug in some.
-breadfruit in some regions are clearly exclusively of breadnut heritage

II. Breadfruit Origins

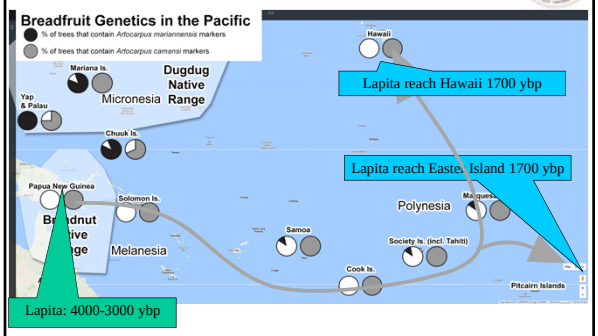
C. Hypothesis Testing (Zerega et al. 2005)

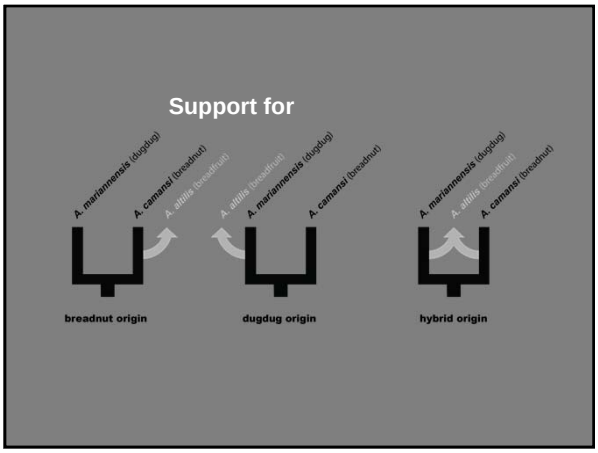
3. Does archeaology help explain this pattern?



II. Breadfruit Origins

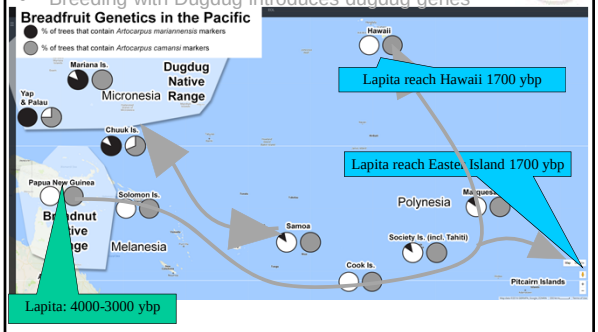
Breadfruit initially derived from breadnut





II. Breadfruit Origins

- Later trade with people of Micronesia
- Breeding with Dugdug introduces dugdug genes



Support for 1) the *A. camansi*-origin hypothesis & 2) the hybrid hypothesis

Breadnut origin followed by introgression with dugdug