Learning the CBGM by Design

Greek Paul Project Webinar
28 April 2022

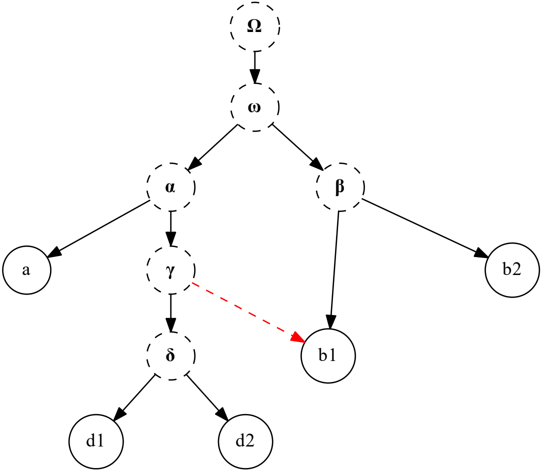
Joey McCollum
Australian Catholic University
Institute for Religion and Critical Inquiry
✉ james.mccollum@myacu.edu.au
🐦 @jamesjmccollum
jjmccollum

ACU INSTITUTE FOR RELIGION & CRITICAL INQUIRY

About the CBGM

- Developed over thirty years by Gerd Mink, culminating in the latest updates to the *Editio Critica Maior* (*ECM*)
- Recommended reading:
    - Gerd Mink, "Problems of a Highly Contaminated Tradition: The New Testament. Stemmata of Variants as a Source of a Genealogy for Witnesses," in *Studies in Stemmatology II*, ed. Pieter van Reenen, August den Hollander, and Margot van Mulken (Amsterdam: John Benjamins Publishing, 2004), 13–85
    - Peter J. Gurry, *A Critical Examination of the Coherence-Based Genealogical Method in New Testament Textual Criticism*, NTTSD 55 (Leiden: Brill, 2017)
    - Tommy Wasserman and Peter J. Gurry, *A New Approach to Textual Criticism: An Introduction to the Coherence-Based Genealogical Method*, RBS 80 (Atlanta, GA: SBL Press, 2017)
    - Andrew Charles Edmondson, "An Analysis of the Coherence-Based Genealogical Method Using Phylogenetics," (PhD diss., University of Birmingham, 2019), https://etheses.bham.ac.uk/id/eprint/9150/

- Intended to solve *contamination*, or mixture across branches of the textual tradition



- Key assumption: *no hypothetical ancestors* (except the *Ausgangstext* A)
- Other important assumptions:
  1. Scribes typically copied their exemplars with fidelity.
  2. If a scribe introduced a variant, then it came from some other reading.
  3. Scribes typically used fewer sources rather than many.
  4. Scribes typically used closely related sources rather than distant ones.

About the CBGM

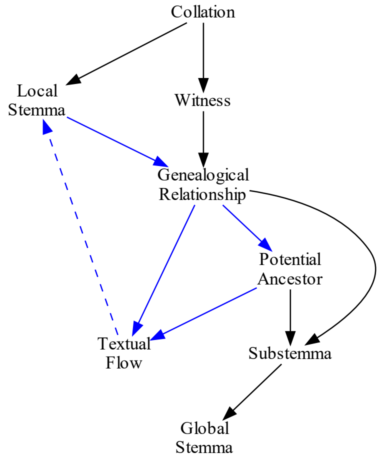
- Key assumption: *no hypothetical ancestors* (except the *Ausgangstext* A)
- Other important assumptions:
  1. Scribes typically copied their exemplars with fidelity.
  2. If a scribe introduced a variant, then it came from some other reading.
  3. Scribes typically used fewer sources rather than many.
  4. Scribes typically used closely related sources rather than distant ones.

About the CBGM

- *Not* a new methodology for evaluating variant readings, but a "meta-approach" to be used on top of existing methods
- *Not* a way to make computers do textual criticism, but a way for them to help us refine human judgments

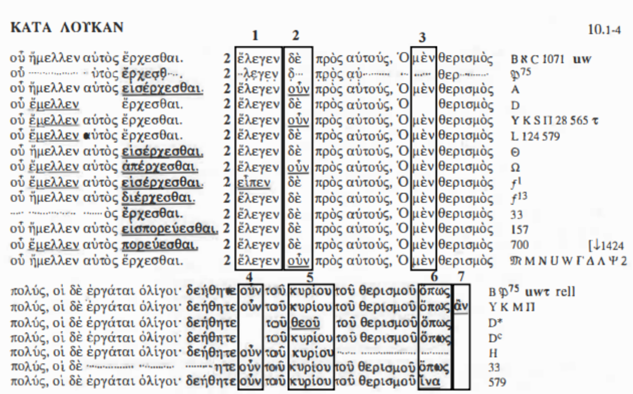
Roadmap

- “Iterative workflow” highlighted in blue



Collation

- To compare manuscripts’ texts, we must first align them at independent *variation units*
- *Variant readings* occur at variation units



ΚΑΤΑ ΛΟΥΚΑΝ 10.1-4

		1	2		3		
οὗ ἤμελλεν αὐτὸς ἔρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	B ℵ C 1071 **uw**
οὗ ………… ὐτὸς ἔρχεσθ….	2	…λεγεν	δ…	πρὸς αὐ………	……	θερ………	𝔓^{75}
οὗ ἤμελλεν αὐτὸς εἰσέρχεσθαι.	2	ἔλεγεν	οὖν	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	A
οὗ ἔμελλεν ἔρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ		θερισμὸς	D
οὗ ἔμελλεν αὐτὸς ἔρχεσθαι.	2	ἔλεγεν	οὖν	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	Y K S Π 28 565 **τ**
οὗ ἔμελλεν αὐτὸς ἔρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	L 124 579
οὗ ἤμελλεν αὐτὸς εἰσέρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	Θ
οὗ ἔμελλεν αὐτὸς ἀπέρχεσθαι.	2	ἔλεγεν	οὖν	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	Ω
οὗ ἔμελλεν αὐτὸς εἰσέρχεσθαι.	2	εἶπεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	f^{1}
οὗ ἤμελλεν αὐτὸς διέρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	f^{13}
…… ………… ……ὸς ἔρχεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	33
οὗ ἤμελλεν αὐτὸς εἰσπορεύεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	157
οὗ ἔμελλεν αὐτὸς πορεύεσθαι.	2	ἔλεγεν	δὲ	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	700 [↓1424
οὗ ἤμελλεν αὐτὸς ἔρχεσθαι.	2	ἔλεγεν	οὖν	πρὸς αὐτούς, Ὁ	μὲν	θερισμὸς	𝔐 M N U W Γ Δ Λ Ψ 2

	4		5		6	7	
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε	οὖν	τοῦ	κυρίου	τοῦ θερισμοῦ	ὅπως		B 𝔓^{75} **uwτ** rell
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε	οὖν	τοῦ	κυρίου	τοῦ θερισμοῦ	ὅπως	ἄν	Y K M Π
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε		τοῦ	θεοῦ	τοῦ θερισμοῦ	ὅπως		D*
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε		τοῦ	κυρίου	τοῦ θερισμοῦ	ὅπως		D^{c}
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε	οὖν	τοῦ	κυρίου	…… …………	………		H
πολύς, οἱ δὲ ………… ……… ……ητε	οὖν	τοῦ	κυρίου	τοῦ θερισμοῦ	ὅπως		33
πολύς, οἱ δὲ ἐργάται ὀλίγοι· δεήθητε	οὖν	τοῦ	κυρίου	τοῦ θερισμοῦ	ἵνα		579

(Source: Swanson, *New Testament Greek Manuscripts, Luke*, 183)

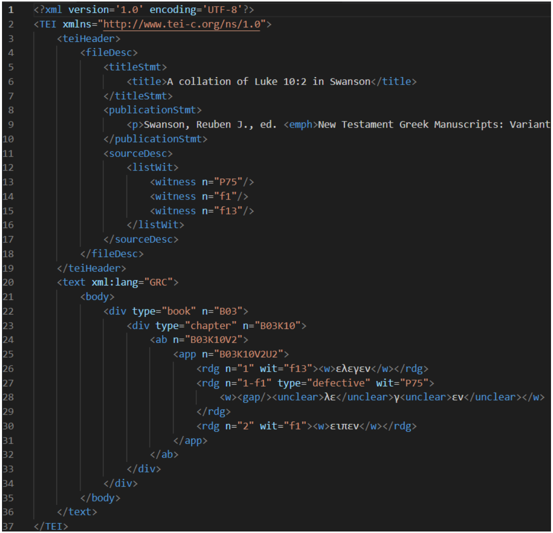
Collation

- Variation units serve as our points of comparison between witnesses in the CBGM
- Think of them as the columns of a table and the witnesses as rows

	3Jo 1:1/2	3Jo 1:1/6	3Jo 1:1/8	···	3Jo 1:15/23
GA 69	a	af1	a	···	a
GA 1739	a	a	b	···	a
GA 2243	b	a	a	···	a

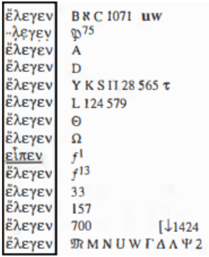
Collation

- This is readily encoded in TEI XML format

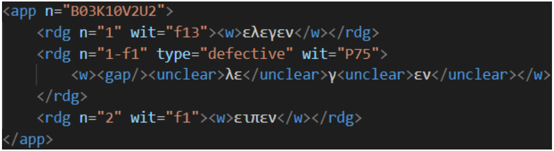


```xml
<?xml version='1.0' encoding='UTF-8'?>
<TEI xmlns="http://www.tei-c.org/ns/1.0">
    <teiHeader>
        <fileDesc>
            <titleStmt>
                <title>A collation of Luke 10:2 in Swanson</title>
            </titleStmt>
            <publicationStmt>
                <p>Swanson, Reuben J., ed. <emph>New Testament Greek Manuscripts: Variant
            </publicationStmt>
            <sourceDesc>
                <listWit>
                    <witness n="P75"/>
                    <witness n="f1"/>
                    <witness n="f13"/>
                </listWit>
            </sourceDesc>
        </fileDesc>
    </teiHeader>
    <text xml:lang="GRC">
        <body>
            <div type="book" n="B03">
                <div type="chapter" n="B03K10">
                    <ab n="B03K10V2">
                        <app n="B03K10V2U2">
                            <rdg n="1" wit="f13"><w>ελεγεν</w></rdg>
                            <rdg n="1-f1" type="defective" wit="P75">
                                <w><gap/><unclear>λε</unclear>γ<unclear>εν</unclear></w>
                            </rdg>
                            <rdg n="2" wit="f1"><w>ειπεν</w></rdg>
                        </app>
                    </ab>
                </div>
            </div>
        </body>
    </text>
</TEI>
```

Collation



ἔλεγεν	B ℵ C 1071 **uw**
..λ̣ε̣γε̣ν̣	𝔓^{75}
ἔλεγεν	A
ἔλεγεν	D
ἔλεγεν	Y K S Π 28 565 τ
ἔλεγεν	L 124 579
ἔλεγεν	Θ
ἔλεγεν	Ω
εἶπεν	f^{1}
ἔλεγεν	f^{13}
ἔλεγεν	33
ἔλεγεν	157
ἔλεγεν	700 [↓1424
ἔλεγεν	𝔐 M N U W Γ Δ Λ Ψ 2

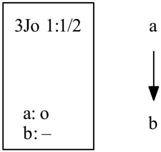


```
<app n="B03K10V2U2">
    <rdg n="1" wit="f13"><w>ελεγεν</w></rdg>
    <rdg n="1-f1" type="defective" wit="P75">
        <w><gap/><unclear>λε</unclear>γ<unclear>εν</unclear></w>
    </rdg>
    <rdg n="2" wit="f1"><w>ειπεν</w></rdg>
</app>
```

```
reading_support = {
    "f13": "1",
    "P75": "1-f1",
    "f1": "2"
}
```

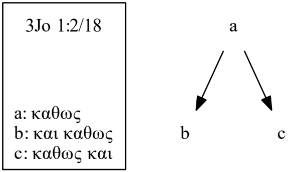
The Local Stemma

- The basic unit of comparison
- One for each variation unit
- A graphical representation of our judgments of readings
- Kurt Aland’s “local genealogical” principle



3Jo 1:1/2

a: ο
b: –



3Jo 1:2/18

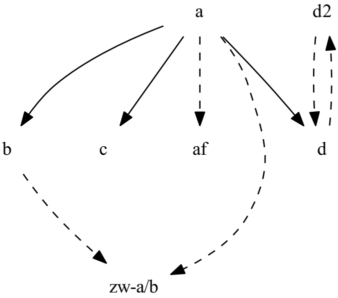
a: καθως
b: και καθως
c: καθως και

The Local Stemma

- Some are more complicated
  - *defective* readings (e.g., misspellings, reconstructions)
  - *orthographic* readings (e.g., regional differences)
  - *split* attestations of the same reading (coincidental emergence)
  - *ambiguous* readings (can be reconstructed as more than one reading)
- Some of these may be collapsed with other substantive readings

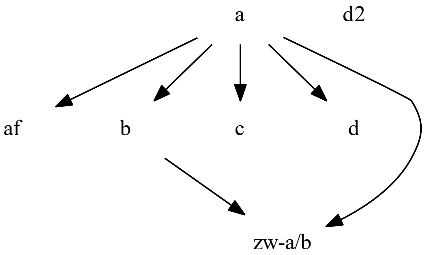
3Jo 1:4/22-26

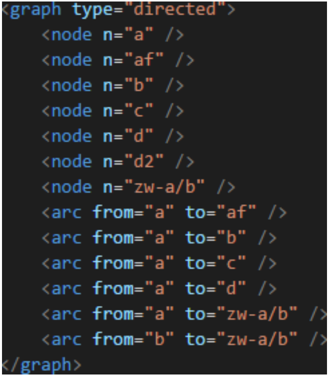
a: εν αληθεια περιπατουντα
af: εν αληθεια περιπατουντο
b: εν τη αληθεια περιπατουντα
c: περιπατουντα εν αληθεια
d: τη αληθεια περιπατουντα
zw-a/b: εν [13-15]τουντα



The Local Stemma

- Computationally, just a directed graph.





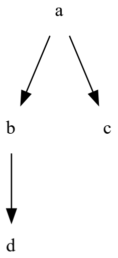
```
<graph type="directed">
    <node n="a" />
    <node n="af" />
    <node n="b" />
    <node n="c" />
    <node n="d" />
    <node n="d2" />
    <node n="zw-a/b" />
    <arc from="a" to="af" />
    <arc from="a" to="b" />
    <arc from="a" to="c" />
    <arc from="a" to="d" />
    <arc from="a" to="zw-a/b" />
    <arc from="b" to="zw-a/b" />
</graph>
```

The Local Stemma

- Relationships between readings are determined by checking for a path between them
- $a = b$ (agreement): path of length 0
- $a > b$ (prior): path of length > 0 from a to b
- $a < b$ (posterior): path of length > 0 from b to a
- NOREL (no relationship): no path from a to b, but both have a *common ancestor*

Acts 2:5/26-30

a: υπο τον ουρανον
b: υπο των ουρανων
c: υπο του ουρανου
d: υπ ουρανον

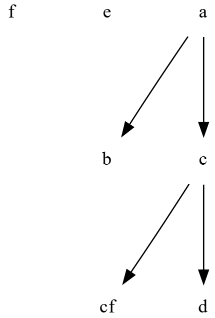


The Local Stemma

- UNCL (unclear): same as NOREL, but no common ancestor (reserved for when we don't know where a reading fits in the stemma)
- We say that one reading *explains* another if
  - it is the same reading (explanation by agreement), or
  - there is a path of length 1 from it to the other reading
- Lacunae do not have to be explained, and they cannot explain readings

3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –



Witnesses

- For the CBGM's purposes, a *witness* is a sequence of readings
- Typically, the *text* of a known manuscript, minus the material baggage (date, provenance, etc.)
    - "How texts relate" ≠ "How manuscripts relate"

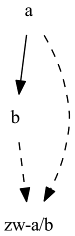
	3Jo 1:1/2	3Jo 1:1/6	3Jo 1:1/8	···	3Jo 1:15/23
GA 69	a	af1	a	···	a
GA 1739	a	a	b	···	a
GA 2243	b	a	a	···	a

Witnesses

- Versions and fathers can also be treated as witnesses
- But back-translation may be ambiguous, and patristic citations may be "lacunose"

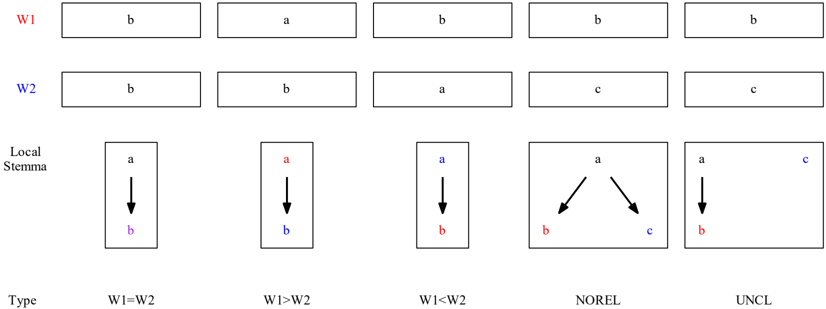
3Jo 1:1/2

a:	o	... CosmIn. PsOec. S:H
b:	–	467. 2243. 2828
zw-a/b:		L:VT. K:SB. S:Ph



Genealogical Relationships

- The relationship of two witnesses is the overall pattern *of the relationships of their readings* where both are extant
- The *cost* of a genealogical relationship is the number of explained readings that are not agreements (so the cost in the example below is 1)

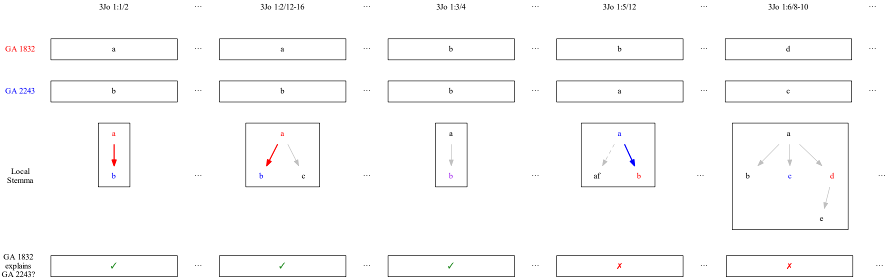


W1	b	a	b	b	b
W2	b	b	a	c	c
Local Stemma	a b	a b	a b	a b c	a c b
Type	W1=W2	W1>W2	W1<W2	NOREL	UNCL

Genealogical Relationships

- It is convenient to encode genealogical relationships with *bitmaps*

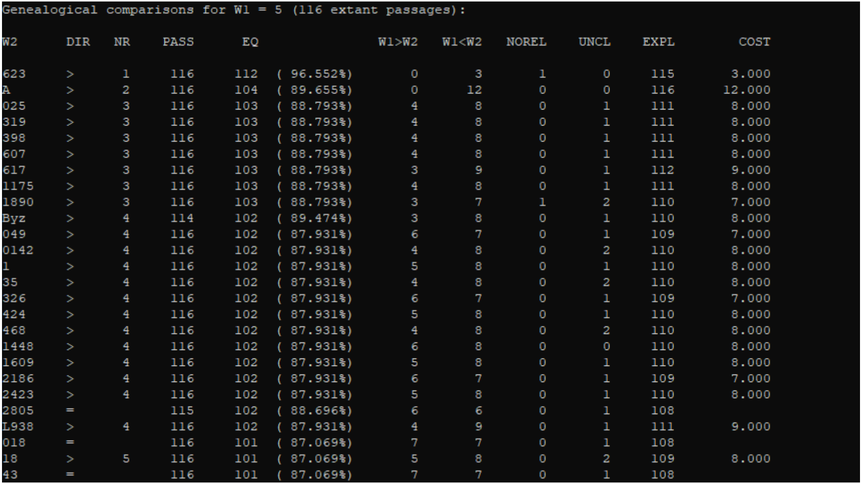
$$
\begin{aligned}
\texttt{agree} &= [1,0,0,0,0] \\
\texttt{prior} &= [0,1,0,0,0] \\
\texttt{posterior} &= [0,0,1,0,0]
\end{aligned}
\qquad
\begin{aligned}
\texttt{norel} &= [0,0,0,1,0] \\
\texttt{uncl} &= [0,0,0,0,1] \\
\texttt{expl} &= [1,0,1,0,0] \\
\texttt{cost} &= 1
\end{aligned}
$$



	3Jo 1:1/2	…	3Jo 1:2/12-16	…	3Jo 1:3/4	…	3Jo 1:5/12	…	3Jo 1:6/8-10	…
GA 1832	a	…	a	…	b	…	b	…	d	…
GA 2243	b	…	b	…	b	…	a	…	c	…
Local Stemma		…		…		…		…		…
GA 1832 explains GA 2243?	✓	…	✓	…	✓	…	✗	…	✗	…

Genealogical Relationships

- For d units and n witnesses, $\sim n^2 d$ comparisons as one-time work
- The `compare_witnesses` module (below) presents this computed data



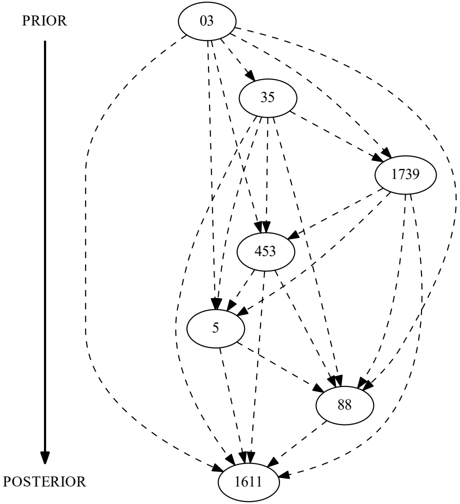
```
Genealogical comparisons for W1 = 5 (116 extant passages):

W2      DIR   NR    PASS      EQ               W1>W2   W1<W2   NOREL    UNCL    EXPL        COST

623     >      1     116     112  ( 96.552%)       0       3       1       0     115       3.000
A       >      2     116     104  ( 89.655%)       0      12       0       0     116      12.000
025     >      3     116     103  ( 88.793%)       4       8       0       1     111       8.000
319     >      3     116     103  ( 88.793%)       4       8       0       1     111       8.000
398     >      3     116     103  ( 88.793%)       4       8       0       1     111       8.000
607     >      3     116     103  ( 88.793%)       4       8       0       1     111       8.000
617     >      3     116     103  ( 88.793%)       3       9       0       1     112       9.000
1175    >      3     116     103  ( 88.793%)       4       8       0       1     111       8.000
1890    >      3     116     103  ( 88.793%)       3       7       1       2     110       7.000
Byz     >      4     114     102  ( 89.474%)       3       8       0       1     110       8.000
049     >      4     116     102  ( 87.931%)       6       7       0       1     109       7.000
0142    >      4     116     102  ( 87.931%)       4       8       0       2     110       8.000
1       >      4     116     102  ( 87.931%)       5       8       0       1     110       8.000
35      >      4     116     102  ( 87.931%)       4       8       0       2     110       8.000
326     >      4     116     102  ( 87.931%)       6       7       0       1     109       7.000
424     >      4     116     102  ( 87.931%)       5       8       0       1     110       8.000
468     >      4     116     102  ( 87.931%)       4       8       0       2     110       8.000
1448    >      4     116     102  ( 87.931%)       6       8       0       0     110       8.000
1609    >      4     116     102  ( 87.931%)       5       8       0       1     110       8.000
2186    >      4     116     102  ( 87.931%)       6       7       0       1     109       7.000
2423    >      4     116     102  ( 87.931%)       5       8       0       1     110       8.000
2805    =            115     102  ( 88.696%)       6       6       0       1     108
L938    >      4     116     102  ( 87.931%)       4       9       0       1     111       9.000
018     =            116     101  ( 87.069%)       7       7       0       1     108
18      >      5     116     101  ( 87.069%)       5       8       0       2     109       8.000
43      =            116     101  ( 87.069%)       7       7       0       1     108
```

Potential Ancestors

- Potential ancestor = “more prior than posterior readings”

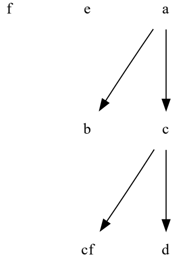


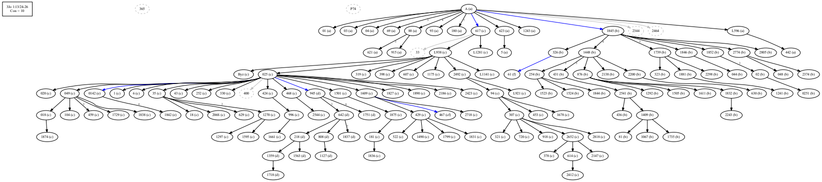
Textual Flow at a Variation Unit

- *Textual flow* is a tool for helping us revise our judgments in a local stemma
- *Not* a global stemma (our ultimate goal), but still important

3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –



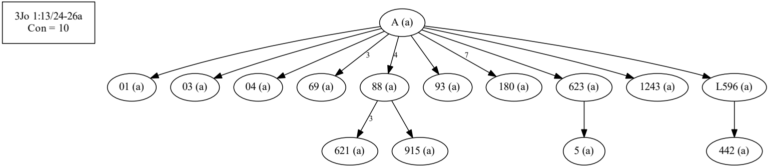


Textual Flow at a Variation Unit

- How do we find a given witness's *textual flow ancestor*?
- We specify a *connectivity limit* κ (i.e., a radius of "close-enough" neighbors)
- Then, for each witness:
  1. List its potential ancestors, sorted from most agreement to least
  2. If one of the first κ has the same reading at this unit, then select it
  3. If not, then choose the first (non-lacunose) potential ancestor
- Core idea: use *general relationships* (between witnesses) to find *specific relationships* (between readings in a local stemma)

Textual Flow for a Variant Reading

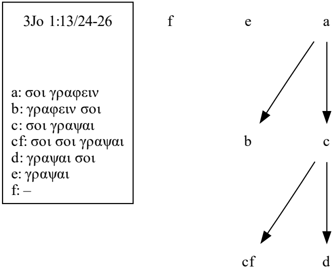
- Often, we just want to know the textual flow for witnesses with a specific reading



- (Numbers on edges represent the rank of the closest potential ancestor with the same reading, if it’s not 1)

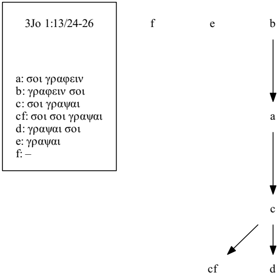
Textual Flow for a Variant Reading

- We can use it to evaluate alternate hypotheses about the initial text (A)



3Jo 1:13/24-26

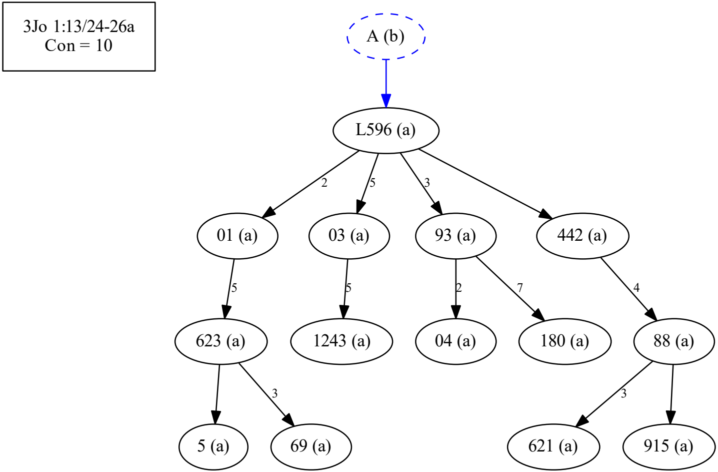
a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –



3Jo 1:13/24-26

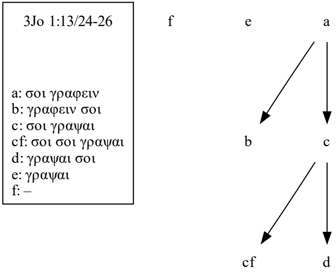
a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –

Textual Flow for a Variant Reading



Textual Flow for a Variant Reading

- Or, we can look only at the parts of textual flow where a reading gets changed to find the most likely sources of unexplained readings (*e* and *f*)



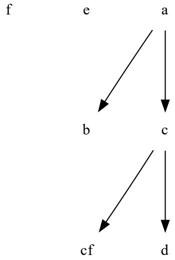
3Jo 1:13/24-26

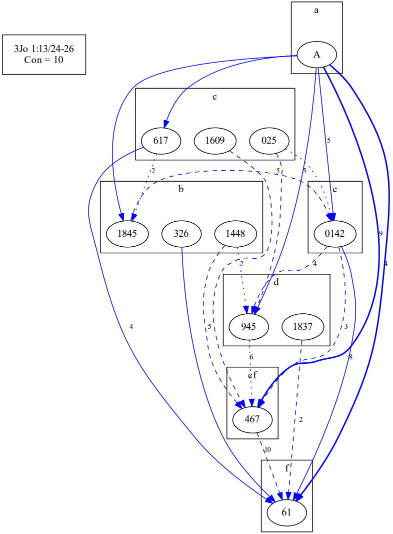
a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –

Textual Flow for a Variant Reading

3Jo 1:13/24-26

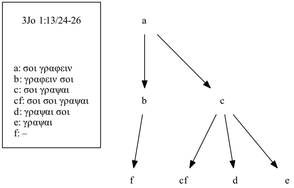
a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –





Textual Flow for a Variant Reading

- Between coherence (a form of external evidence) and internal evidence, we can attempt to explain previous unexplained readings
- A necessary step for our ultimate goal of constructing a global stemma



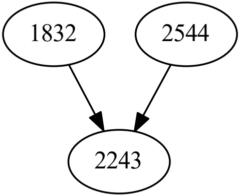
3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –

The Substemma(ta) of a Witness

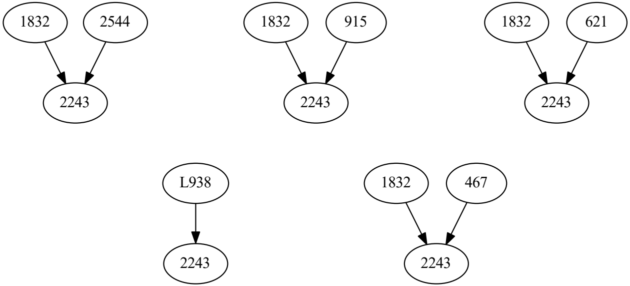
- The *substemma* of a witness is the portion of the global stemma consisting of the witness and its ancestors in the stemma
- Requirement: *every* extant reading in the witness must be explained by a reading in at least one of its ancestors

Explained by GA 1832	···	✗	✓	✓	✓	···
Explained by GA 2544	···	✓	✗	✗	✓	···
Explained by Either	···	✓	✓	✓	✓	···



The Substemma(ta) of a Witness

- A witness may have multiple valid substemma (i.e., ones that explain all of its readings), but some are better than others
- Two of the CBGM's methodological assumptions are important here:
    3. Scribes typically used fewer sources rather than many.
    4. Scribes typically used closely related sources rather than distant ones.
- A balancing act: the substemma {L938} is more parsimonious, but may not explain as many readings by agreement

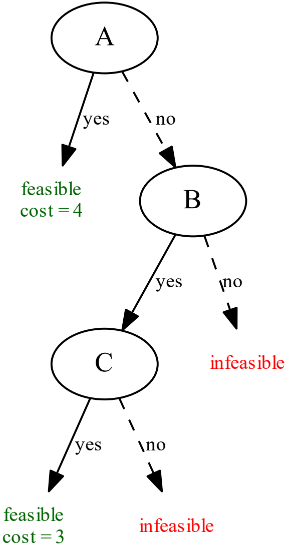


Finding a (Good) Substemma

- Also called *substemma optimization*
- For n potential ancestors, a *weighted set cover* problem with n sets (and $2^n - 1$ combinations to check!)

Substemma	Variation Units Explained				Cost
{A}	✓	✓	✓	✓	4
{B}	✓	✓	✗	✗	1
{C}	✗	✓	✓	✓	2
{A, B}	✓	✓	✓	✓	4+1=5
{A, C}	✓	✓	✓	✓	4+2=6
{B, C}	✓	✓	✓	✓	1+2=3
{A, B, C}	✓	✓	✓	✓	1+2+4=7

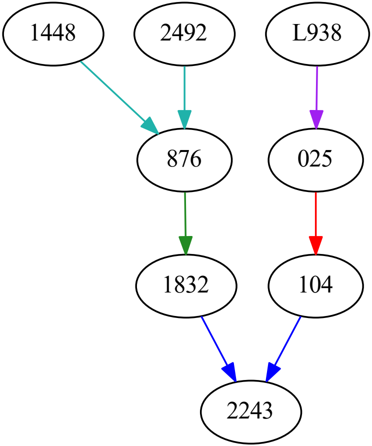
Finding a (Good) Substemma



- If a witness has many potential ancestors, then checking all $2^n - 1$ possible substemmata by brute force is prohibitive
- The *branch-and-bound* heuristic (pictured left) finds all minimum-cost substemmata quickly in practice
- Easily adapted to find all substemmata within a given cost

The Global Stemma

- Just as the local stemma relates readings, the *global stemma* relates witnesses
- Combination of all substemmata into a single graph

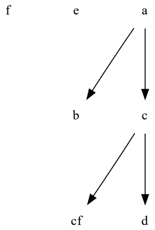


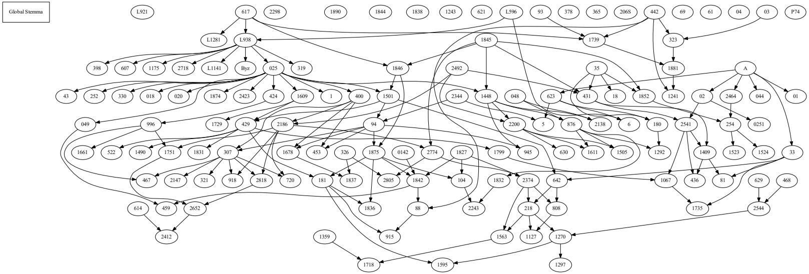
The Global Stemma

- But *every reading in every local stemma* except the initial one must be explained by another reading
- Otherwise…

3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –



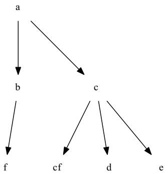


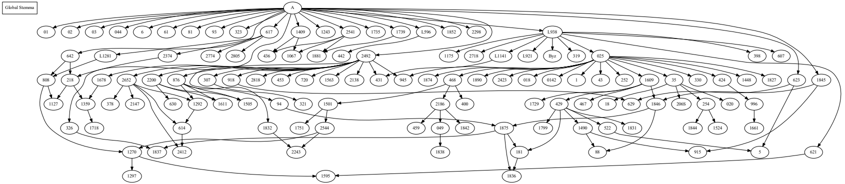
The Global Stemma

- If we “complete” every local stemma (and ignore or manually account for super fragmentary witnesses) …

3Jo 1:13/24-26

a: σοι γραφειν
b: γραφειν σοι
c: σοι γραψαι
cf: σοι σοι γραψαι
d: γραψαι σοι
e: γραψαι
f: –





The Global Stemma

- How is this different than a textual flow diagram?
  - A witness can have more than one ancestor
  - All readings in a witness must be explained by readings in its ancestor(s)
  - More computationally intensive, so takes a bit longer to produce

Field trip

- The `open-cbgm` library (my implementation of the CBGM, based on these principles) is freely available at https://github.com/jjmccollum/open-cbgm, and the standalone command-line utility is available at https://github.com/jjmccollum/open-cbgm-standalone
  - Supported on Windows, Mac, and Linux
- The INTF's official implementation (using a Docker container) is now also available (download and instructions at http://ntvmr.uni-muenster.de/intfblog/-/blogs/download-the-cbgm-docker-container)

Bibliography

Edmondson, Andrew Charles. "An Analysis of the Coherence-Based Genealogical Method Using Phylogenetics." PhD diss., University of Birmingham, 2019. https://etheses.bham.ac.uk/id/eprint/9150/.

Gurry, Peter J. *A Critical Examination of the Coherence-Based Genealogical Method in New Testament Textual Criticism*. NTTSD 55. Leiden: Brill, 2017.

Mink, Gerd. "Problems of a Highly Contaminated Tradition: The New Testament. Stemmata of Variants as a Source of a Genealogy for Witnesses." Pages 13–85 in *Studies in Stemmatology II*. Edited by Pieter van Reenen, August den Hollander, and Margot van Mulken. Amsterdam: John Benjamins Publishing, 2004.

Swanson, Reuben J., ed. *New Testament Greek Manuscripts: Variant Readings Arranged in Horizontal Lines against Codex Vaticanus. Luke.* Sheffield: Sheffield Academic Press, 1995.

Wasserman, Tommy, and Peter J. Gurry. *A New Approach to Textual Criticism: An Introduction to the Coherence-Based Genealogical Method.* RBS 80. Atlanta, GA: SBL Press, 2017.