DYALOG

Glasgow 2024

Tacit Programming in Dyalog

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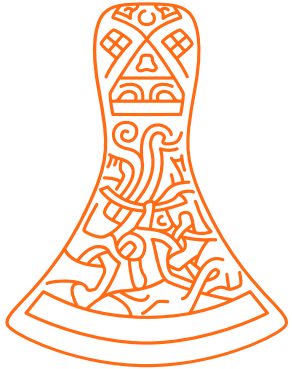

DYALOG

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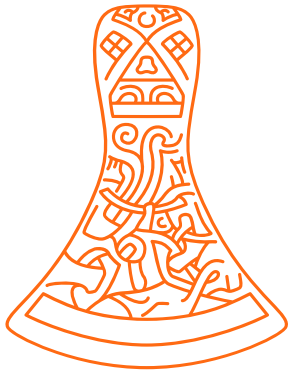
Tacit Programming in Dyalog

Adám Brudzewsky · xpqz.github.io/cultivations/Trains

Rich Park · youtu.be/Enlh5qwwDuY “Train Spotting”

Stefan Kruger · xpqz.github.io/learnapl/tacit



What is tacit programming?

Explicit code mentions arguments:

- Expression `(⌈/N)-⌊/N←3 1 4 1 5`
- Tradfn `∇ R←Range Y …`
- Dfn `{(⌈/⍵)-(⌊/⍵)}`

Tacit code implies arguments:

- Tacit `(⌈/-⌊/)`

You already know some

```
f/    f⍨    ∘.g    f⌿    A∘g    f⌸    f⌸B
```

Operators derive tacit functions

Function composition

```
f⍤g    f⍥g    f⍨    f g h    f∘g
```

Function composition is plumbing that guides arguments to functions

Benefits

- Arguments in operands
- Memorable (like ≠⊆⊢ and +⌿÷≠)
- Adjacency (like ×- and ∨/⍷)
- Brevity (like F⍤⍥C)
- DRY (Don’t Repeat Yourself; like ≡⍤⍴)
- Just a general feeling of superiority and awesomeness

Overview

- Compositional operators (combinators)
- Trains (forks and atops)
- Tools
- Issues
- Reading

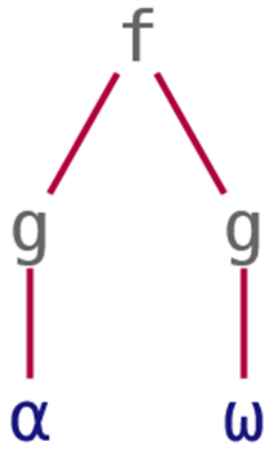
Plenty of exercises throughout

ö Over

The shape of an outer product `α ∘.f ω` is
`(⍴α) , (⍴ω)`

We can write this as
`α ,ö⍴ ω`

“pre-process both”



∘ Beside

Location of α^{th} 1 in each element of ω is

```
α ⊃¨ ⍳¨ ω
```

We can write this as

```
α ⊃∘⍳¨ ω
```

"pre-process right"


```
α f∘g ω
```

⍤ Atop

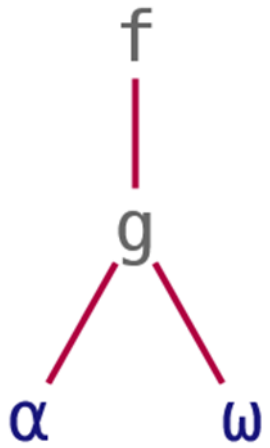
Any-presence of ⍺ in ⍵ is

```
∨/ ⍺ ⍷ ⍵
```

We can write this as

```
⍺ ∨/⍤⍷ ⍵
```

“post-process result”



⍨ Commute

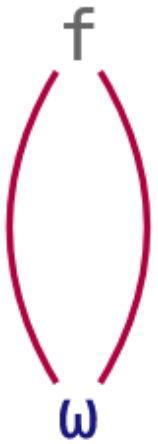
A multiplication table of N is

```
(⍳⍵) ∘.× (⍳⍵)
```

We can write this as

```
∘.×⍨ ⍳⍵
```

“selfie”




```
f⍨ ⍵
```

Tasks: Tacify!

1. `'Hello' {(≠⍺)≡(≠⍵)} 'World'` `1`
2. `'ab' 'cd' 'ab' {+/⍺∈⍵} 'ab' 'de'` `2`
3. `8 100 0 {⍺÷⌊⍵} 2.5` `4 50 0`
4. `10 4 1 0 {⍺⌊⌊⍵} 2.5` `2 2 1 0`
5. `{≠\⍵=⍵} 2 7 1 8 3` `1 0 1 0 1`

Train Introduction

Also a type of composition

Sequence of functions in isolation

- Parenthesised:

```
(+⌿÷≢) 3 1 4 1 5
```

- Assigned

```
Avg←+⌿÷≢
Avg 3 1 4 1 5
```

Most common mistake

```
      +⌿÷≢ 3 1 4 1 5
0.2

     (+⌿÷≢)3 1 4 1 5
2.8
```

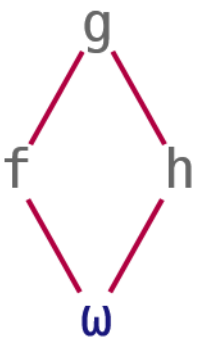
Discussion: Writing Trains

```
(f Y) + (h Y)   →   (f + h) Y
(f Y) + (  Y)   →   (f + ⊢) Y
```

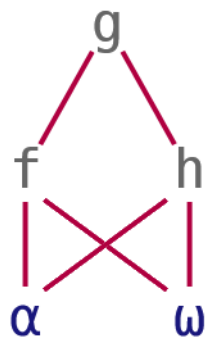
```
(X f Y) + (X h Y)   →   X (f + h) Y
(X    ) + (X h Y)   →   X (⊣ + h) Y
```

Discussion: Writing Trains

```
(f Y) g (h Y)   →   (f g h) Y
(f Y) g (  Y)   →   (f g ⊢) Y
```



(fgh)ω



α(fgh)ω

```
(X f Y) g (X h Y)   →   X (f g h) Y
(X   ) g (X h Y)   →   X (⊣ g h) Y
```

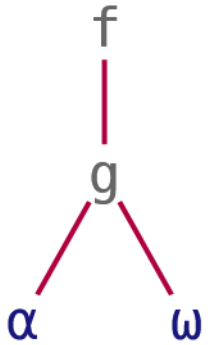
Discussion: Writing Trains

```
   (f Y) g (h Y)   →   (f g h) Y
   (f Y) g (  Y)   →   (f g ⊢) Y
         g (h Y)   →   (  g h) Y

(X f Y) g (X h Y)   →   X (f g h) Y
(X   ) g (X h Y)   →   X (⊣ g h) Y
         g (X h Y)   →   X (  g h) Y
```

Discussion: Writing Trains

```
(f Y) g (h Y)   →   (f g h) Y
(f Y) g (  Y)   →   (f g ⊢) Y
      f (g Y)   →   (  f g) Y

(X f Y) g (X h Y)   →   X (f g h) Y
(X    ) g (X h Y)   →   X (⊣ g h) Y
      f (X g Y)   →   X (  f g) Y
```

(fg)ω



α(fg)ω

Train Details

Some parts can be arrays:

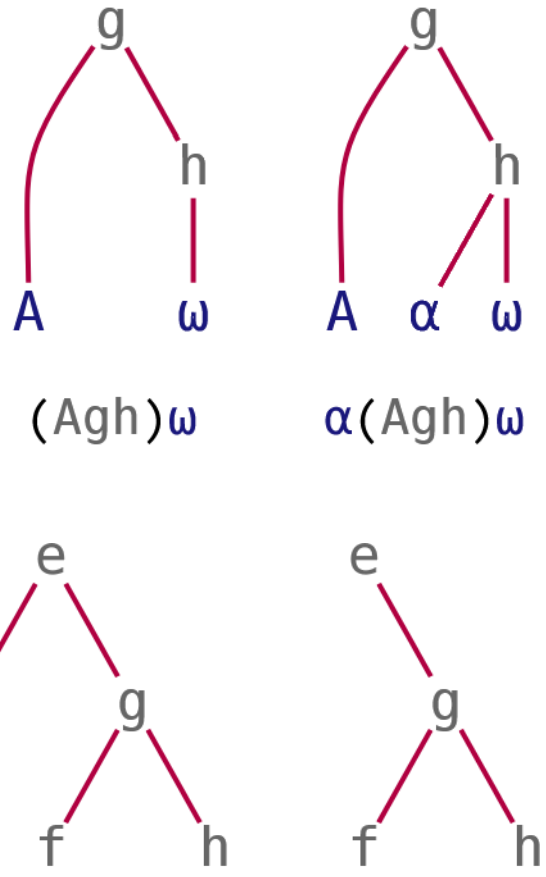
- `A g h` is `{A} g h`

Two sub-types of trains:

- Fork: `f g h` and `A g h`
- Atop: `f g`

Longer trains:

- `(d e f g h)` is `(d e (f g h))`
- `(e f g h)` is `(e (f g h))`



Example: Writing a Train

```
      {∧/ (⌈\⍵) = ⍵}  1 3 5 6 7
1
      {∧/ (⌈\⍵) = (⊢⍵)}  1 3 5 6 7
1
      {∧/ (⌈\ = ⊢) ⍵}  1 3 5 6 7
1
      {(∧/ ⌈\ = ⊢) ⍵}  1 3 5 6 7
1
      (∧/ ⌈\ = ⊢)  1 3 5 6 7
1
```

Tasks: Convert dfn to tacit

1. `{1+⍵} 2 7 1 8`
2. `3 1 4 {(⍺∪⍵)~(⍺∩⍵)} 1 6 1`
3. `{∪⍵∨⍳⍵} 10`
4. `2 {(⍺⊃⍵)⊃⍵} 2 7 1 8 3`
5. `{⍵*2} 2 7 1 8 3`

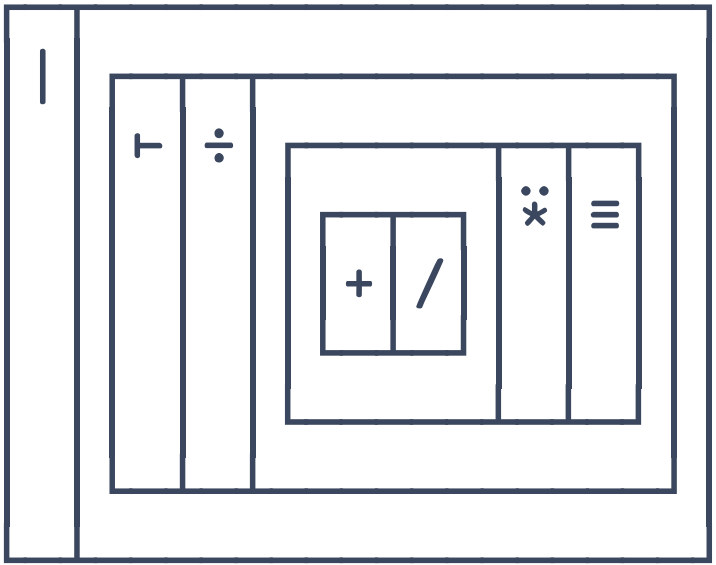
Bonus:
Find 3 ways to do this!

```
3 8 2 9

3 4 6

1 2 5 10

7

4 49 1 64 9
```

Amazing tool: `]box on`

```
]box on
```

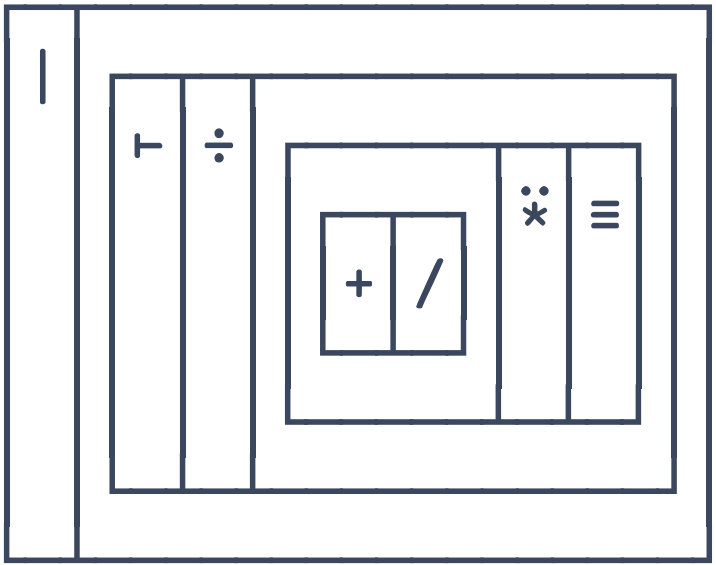
```
|⊢÷+/⍤≡
```



```
]box on -t=…
```

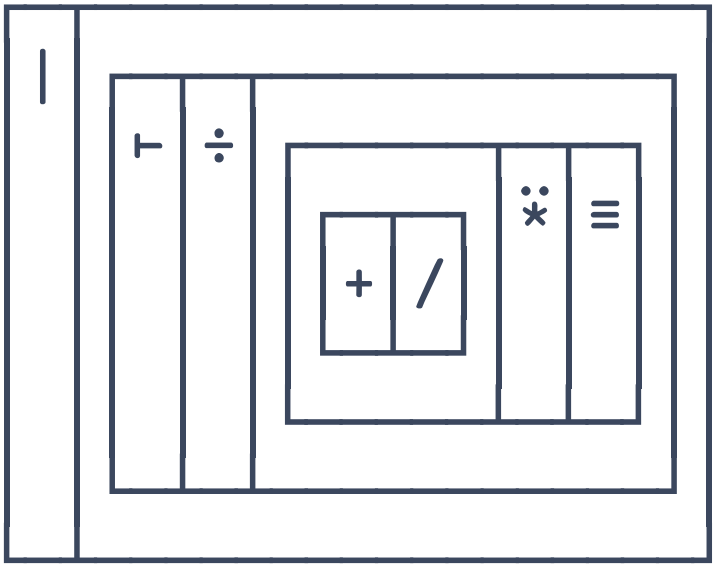
```
|⊢÷+/⍤≡
```

```
-t=box
```

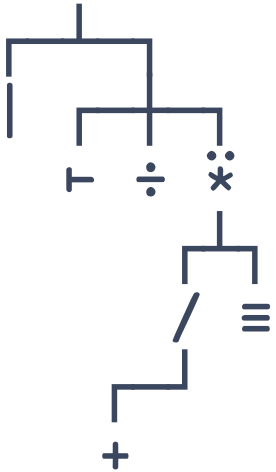


]box on -t=… |⊢÷+/⍤≡

-t=box

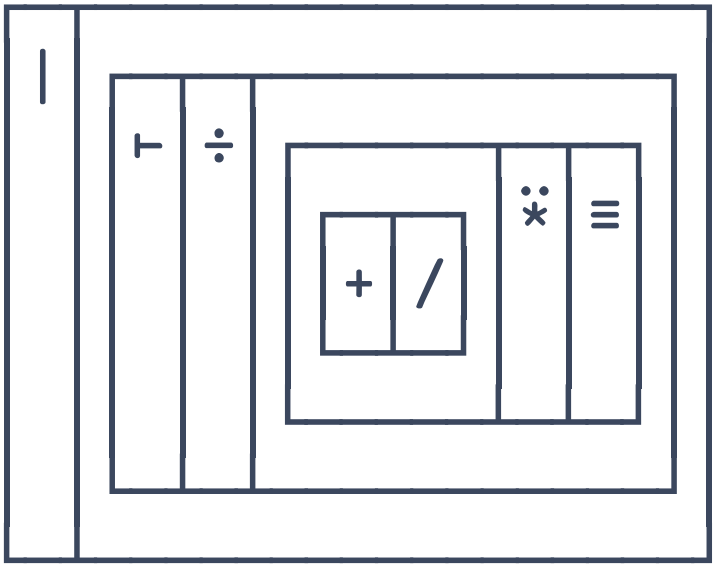


-t=tree

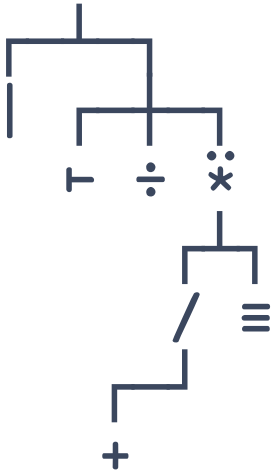


]box on -t=… |⊢÷+/⍤≡

-t=box



-t=tree



-t=parens

```
|(⊢÷((+/)⍤≡))
```

Tasks: Convert dfn to tacit

1. `{(⊖⍵)⊥(⊖⍵)} 1 1 1 0 1 1 0 0` → `3`
2. `',;' {(~⍵∊⍺)⊆⍵} 'ab,de;fgh'` → `ab de fgh`

```
nums←2 7 1 8 3
```

3. `4 {(⍺+≠⍵)÷⍺} nums` → `4.5 4.75`
4. `{(+≠⍵)÷≢⍵} nums` → `4.2`
5. **Bonus task:** Combine 3 & 4 into an ambivalent function.

Issues

- Arguments in operands
- Lots of monadic functions
- Dotting, Assignment, Recursion
- Selection

Issues: Arguments in operands

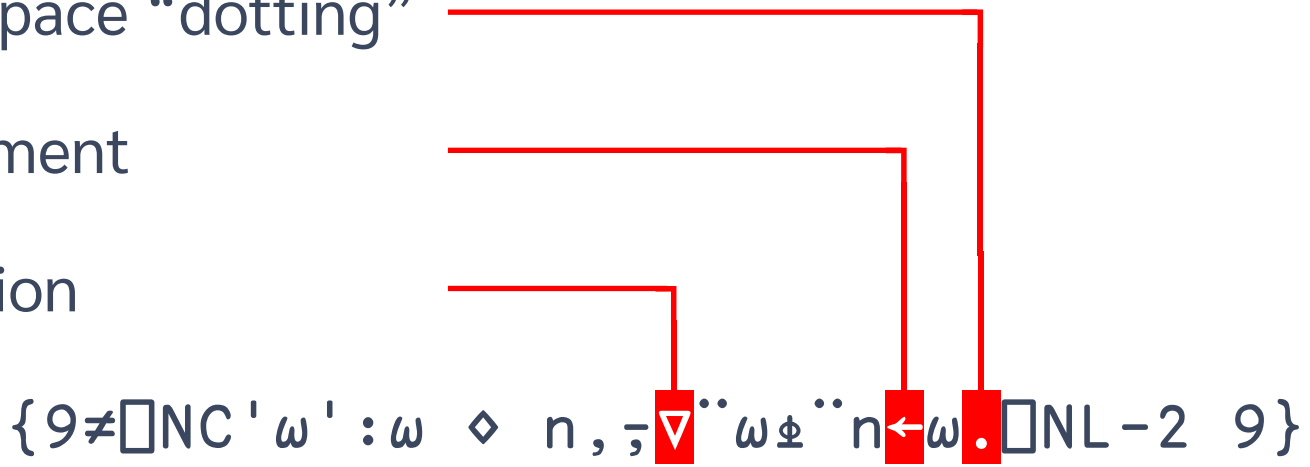
```
      10 {x←⍺ ⋄ ⍵@{x<⍵}⍵} 1 2 13 14 5 16 7 18
1 2 18 16 5 14 7 13
      10 {      ⍵@(⍺<⊢)⍵} 1 2 13 14 5 16 7 18
1 2 18 16 5 14 7 13

      2 {(⍵⍤⌽⍤⍳⍺)⍵} 3 3⍴⍳9
9 8 7
6 5 4
3 2 1
```

Issues: Lots of monadic functions

```
{⍵+≠↑⍵⍨⍵}
⍵⍤(+≠)⍤↑⍤(⍵⍨)
⍵(+≠(↑⍵⍨))
⍵+≠⍤↑⍤(⍵⍨)
⍵(+≠⍤↑⍵⍨)
```

Issues: Recursion, Assignment, Dotting

- Namespace “dotting”
- Assignment
- Recursion



Issues: Selection

```
      {(3>⍵)≠⍵} 3 1 4 1 5
4 5
       (3∘>≠⊢)  3 1 4 1 5
SYNTAX ERROR
       (3∘>≠ ⊢) 3 1 4 1 5
SYNTAX ERROR
     (3∘> ⊢⍤≠ ⊢)3 1 4 1 5
4 5
        3∘>⍤≠   3 1 4 1 5
```

20.0 Conference Edition

Issues: Selection

```
      'aeiou' {ω[α⍋ω]} 'hello world'
eoohll wrld
      'aeiou' {ω[]⍨α⍋ω} 'hello world'
LENGTH ERROR
      'aeiou' {ω[]⍨⊂α⍋ω} 'hello world'
eoohll wrld
      'aeiou'  (⊂⍤⍋[]⊢)  'hello world'
eoohll wrld
      'aeiou'   (⍋⍥⊢)   'hello world'
```

21.0?

Reading Tacit

operator scope

trains

putting it all together

Reading Tacit: operator scope

```
=∘⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤⍥0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤⍥0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍋⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⌽⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍋⍤0 1⍨∘⍳5
```

Reading Tacit: operator scope

```
=∘⍤⍥0 1⍨∘⍳5
(((=∘⍤)⍥0 1)⍨)∘⍳)5
```

Reading Tacit: operator scope

```
=∘⍋⍤0 1⍨∘⍳5
```

```
(((=∘⍋)⍤0 1)⍨)∘⍳)5
```

Reading Tacit: operator scope

```
=∘⍧⍤0 1⍨∘⍳5
```

```
(((=∘⍧)⍤0 1)⍨)∘⍳)5
```

Reading Tacit: operator scope

```
=∘⍤0 1⍨∘⍳5
(((=∘⍤)0 1)⍨)∘⍳)5
```

Reading Tacit: operator scope

```
=∘⍋⍤0 1⍨∘⍳5
((((=∘⍋)⍤0 1)⍨)∘⍳)5
```

Writing Tacit: operator scope

```
1  {α⌈+/ω} 3 1 ¯4 1 ¯5
1    ⌈∘+/  3 1 ¯4 1 ¯5
1    ⌈∘+/  3 1 ¯4 1 ¯5
1   (⌈∘+)/ 3 1 ¯4 1 ¯5
1   ⌈∘(+/) 3 1 ¯4 1 ¯5
1  {α⌈+/ω} 3 1 ¯4 1 ¯5
```

Tasks: Convert tacit to dfn

1. Monadic `≠∘+⍨`
2. Monadic `↑⍤⊢,⍤⊂`
3. Dyadic `↑⍤⊢,⍤⊂`
4. Dyadic `+∘÷⍣≡`

Bonus tasks:

5. Combine 2. and 3. into a single ambivalent function
   Hint: use the `{⍺←… ⋄ …}` syntax

Reading Tacit: trains

```
      (+,-) 4
4 ¯4
```

Reading Tacit: trains

```
      ((+4),(-4))
4 ¯4
```

Reading Tacit: trains

```
      (4,¯4)
4 ¯4
```

Reading Tacit: trains

```
      10 (+,-) 4
14 6
```

Reading Tacit: trains

```
      ((10+4),(10-4))
14 6
```

Reading Tacit: trains

```
      (14,6)

14 6
```

Reading Tacit: trains

```
(|+⌿÷1⌈≢) 3 ¯1 ¯4 1 ¯5
```

Reading Tacit: trains

```
(| +⌿ ÷ 1 ⌈ ≢)  3 ¯1 ¯4 1 ¯5
```

Reading Tacit: trains

```
(|   +⌿                    ÷ 1 ⌈   ≢)   3 ¯1 ¯4 1 ¯5
(| (+⌿3 ¯1 ¯4 1 ¯5) ÷ 1 ⌈ (≢3 ¯1 ¯4 1 ¯5))
(|   ¯6                   ÷ 1 ⌈   5                 )
(|   ¯6                   ÷     5                  )
(|                    ¯1.2                        )
                       1.2
```

Reading Tacit: trains

```
      (| +⌿ ÷ 1 ⌈ ≠)  3 ¯1 ¯4 1 ¯5
(| (+⌿3 ¯1 ¯4 1 ¯5) ÷ 1 ⌈ (≠3 ¯1 ¯4 1 ¯5))
          (| ¯6 ÷ 1 ⌈ 5)
            (| ¯6 ÷ 5)
              (| ¯1.2)
                1.2
```

Reading Tacit: putting it all together

```
(⊂⍥⍰⍨⍥≠⍬⊢) 'AEIOU'
```

Reading Tacit: putting it all together

```
(⊂⍤⍰⍨∘≠ ⍬ ⊢)  'AEIOU'
```

Reading Tacit: putting it all together

```
(⊂⍤⍰⍨∘≠                  ⌷  ⊢)  'AEIOU'
((⊂⍤⍰⍨∘≠ 'AEIOU') ⌷ (⊢'AEIOU'))
```

Reading Tacit: putting it all together

```
 (⊂⍤?⍨∘≢           ⎕  ⊢)  'AEIOU'
((⊂⍤?⍨∘≢ 'AEIOU') ⎕ (⊢'AEIOU'))
((⊂⍤?⍨ 5         ) ⎕  'AEIOU'   )
```

Reading Tacit: putting it all together

```
 (  ⊂⍤?⍨∘≢          ⎕  ⊢)  'AEIOU'
((  ⊂⍤?⍨∘≢ 'AEIOU') ⎕ (⊢'AEIOU'))
((  ⊂⍤?⍨ 5        ) ⎕  'AEIOU'  )
((5 ⊂⍤? 5)          ⎕  'AEIOU'  )
```

Reading Tacit: putting it all together

```
 (  ⊂ ⍤ ?⍨∘≠           ) ⌷  ⊢)  'AEIOU'
((  ⊂ ⍤ ?⍨∘≠ 'AEIOU')  ⌷ (⊢'AEIOU'))
((  ⊂ ⍤ ?⍨ 5          ) ⌷  'AEIOU'  )
((5 ⊂ ⍤ ? 5)           ⌷  'AEIOU'  )
((  ⊂ 5 ? 5)           ⌷  'AEIOU'  )
```

Reading Tacit: putting it all together

```
(⊂⍤⍰⍤⍥≠ ⌷ ⊢)  'AEIOU'
((⊂⍤⍰⍤⍥≠ 'AEIOU') ⌷ (⊢'AEIOU'))
((⊂⍤⍰⍤ 5) ⌷ 'AEIOU')
((5 ⊂⍤⍰ 5) ⌷ 'AEIOU')
   ((⊂ 5 ⍰ 5) ⌷ 'AEIOU')
```

Tasks: Convert tacit to dfn

1. Monadic `××⌊⍤⍥|`
2. Dyadic `⌊∘≢↑⊢`
3. Dyadic `≡⍤(⍞C~∘' ')`
4. Monadic `+/⊢>+/÷≢`

Bonus task:

5. Monadic `⍬≡⊢⊢≡⍬`

Tasks: Determine valence

1. `1+⍴⊥⍣¯1∘+`
2. `+/∧\⍤=`
3. `|⍣¯11|1⊥+\`
4. `1 1⍱∘.+`
5. `,⍤⍱`
6. `/⍤,`

Reading Tacit: tacit.help

Transform tacit APL into dfn form

```
      f ← +⌿÷⊣∘≢
      f Y ⇔ {((+⌿)ω)÷(≢ω)}
X     f Y ⇔ {(α(+⌿)ω)÷α}
```

Arrays: $A, B, C, \ldots$ Functions: $a, b, c, \ldots$

Task: Working with tacit code

This dyadic function is like ⍳ but gives 0 for “not found”:

(⍳ ×≠⍤⍥⊣≥ ⍳)

Make it more efficient by:

- Breaking out ⍳ from the parenthesis
  Hint: Pass all the data you need to the inner function

Then simplify it by:

- Using ⍤⍥ instead of ∘ and adjusting the rest as necessary

Task: Working with tacit code

This function is applied to a non-empty numeric vector:

```
(+\∊⍨∘⍳+/)
```

Make it more efficient by:

- Breaking out `+\` from the parenthesis
- Computing what would be `+/` from `+\`
  Hint: `+/` is the last element of `+\`

Function composition:

- ⍤⍥ *Pre-process both*
- ⍤ *Pre-process right*
- ⍥ *Post-process*
- ⍨ *Selfie*

Operators: long left scope

Trains: odd-even from right

Tools: `]box on -t=…`
tacit.help

Issues with tacit:

Arguments in operands
Lots of monadic functions
Namespace “dotting”
Assignment
Recursion
Selection:

```
⊢⍥≠
⊂⍥… ⍬ …
```