A diagram showing the relationship between system laws, architecture, and various biological and physical systems. The image contains labels and equations related to the concepts of diversity, accuracy, fast and slow rates, and innervation. One notable equation is:

\[ R = \lambda_\alpha T \]

The diagram also highlights the terms 'Optic', 'Vestibular', 'Nerves', and 'Layers' in relation to the architecture and theory.
• Scalar trail and bumps
• Math is easy
• (Experiments are easy)
• Has no additional *internal* structure (e.g. within cortex)
• Beyond what is in the diagram
• What next?

• 1 dimensional
• scalar trail
• scaler bump
Flexible
Centralized
Fast
Slow
Local
Unstable
Layers Diversity Sweet spot SLS?
Theory
bumps
Fast
Rigid
Inaccurate
Flexible
Accurate
Slow
Diverse
bumps
Trail
Layers
System level
Accurate
Flexible
Inaccurate
Rigid
Bumps
Fast Rigid Inaccurate Flexible Accurate Slow Diverse

Trail

Accurate

System level

Diverse

Fast but Fast

Layers

Fast

Accurate Flexible Inaccurate Rigid

Bumps

• Simple map across levels
• Special, convenient case

Nerve level

Architecture

Fast

Accurate Diverse

Law Vestibular Nerve level

Fast

System level

Diverse

Diverse
- Simple map across levels
- Special, convenient case
Diversity enabled sweet spot

- The point of architecture
- Combines diverse layers and levels
- To create functionality that no component alone can achieve
- Diversity crosses levels and layers
What is possible. Every layer and level has its own laws.

R = λαT

System

Fast

Rigid

Slow

Flexible

Accurate

Inaccurate

bumps

trail

Optic

Vestibular

Connective tissue

Veins

Axons

Nerve

Individual ions

Law
What is possible.

Every layer and level has its own laws.

\[ R = \lambda_a T \]
What is possible.

(only) architecture can create sweet spots.

Laws

Diverse

Rigid

Inaccurate

Flexible

Accurate

Slow

Optic

Architecture (only) architecture can create sweet spots.

Levels

R = \lambda T

Vestibular

Nerves

Optic

Bumps
Fast

Rigid

Inaccurate

Flexible

Accurate

Diverse

Slow

Law

Nerves

System

Layers

Laws

Vestibular

Nerves

Bumps

Trail

Theory

Levels

Architecture

Optic

Slow

Fast

Diverse

Accurate

Inaccurate

\( (2^V - |a|)^{-1} \)

\[ + \delta \left( \sum_{i=1}^{T} |a^{i-1}| + |a^T|(2^{2T} - |a|)^{-1} \right) \]

\[ R = \lambda_\alpha T \]
$$(2^V - |a|)^{-1}$$

$$+ \delta \left( \sum_{i=1}^{T} |a^{i-1}| + |a^T|(2^{2T} - |a|)^{-1} \right)$$

$$R = \lambda_\alpha T$$
Diversity enabled Sweet Spot

Fast

Rigid

Flexible

Slow

Optic

Architectural

Diverse

Accurate

Inaccurate

Layers

Laws

Levels

System

Architecture

Theory

Diversity enabled Sweet Spot

Fast

Rigid

Flexible

Slow

Optic

Architectural

Diverse

Accurate

Inaccurate

Layers

Laws

Levels

System

Architecture

Theory
\[ R = \lambda \alpha T \]
Nerve level?  

\[ R = \lambda_\alpha T \]

-log(bandwidth)

\[ \lambda_\alpha \propto \text{area} \]

Equal area

\[ R = \lambda_\alpha T \]

Yorie Nakahira
Terry Sejnowski
Simon Laughlin
(Peter Sterling)

Fast

Diverse?

Optic

Architecture

Law

Myelin sheath

Arteries

Veins

Nerve

Connective tissue

Slow

Diverse?

Accurate

Inaccurate

Fast

Vestibular
cranial nerves

Olfactory

Optic

Vestibular

Nerve level?

Diverse?

Fast

Optic

Architecture

Slow

Optic

Law

Accurate

Vestibular

Inaccurate

$R = \lambda_{\alpha} T$?
Fast

Inaccurate

Accurate

Slow

Law

Architecture

Optic

Vestibular

\( R = \lambda_\alpha T \)

\( \lambda_\alpha \propto \text{area} \)

Equal area

\( \log(T) \)

\( \log(\text{delay}) \)

\( \log(R) \)

\( \log(\text{bandwidth}) \)

Nerve level?

R = \lambda_\alpha T?

Diverse?
<table>
<thead>
<tr>
<th>Cranial Nerves</th>
<th>Avg. Axon Diam. (µm)</th>
<th>No. of Axons per Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olfactory</td>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Optic</td>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Vestibular</td>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Auditory</td>
<td></td>
<td>Small</td>
</tr>
<tr>
<td>Sciatic</td>
<td></td>
<td>Small</td>
</tr>
</tbody>
</table>
\[ \log(T) - \log(R) = Yorie \text{ Nakahira} \]

\[ \lambda_\alpha \propto \text{area} \]

Fast

\[ R = \lambda_\alpha T \]

Accurate

-\log(R)

-\log(\text{bandwidth})

Equal area

Yorie Nakahira
Terry Sejnowski
Simon Laughlin
(Peter Sterling)
Both Turing and Shannon
• let $T \to \infty$ (differently)
• Don’t worry about delays

Turing

Turing lets $R \to \infty$

Shannon

$T \to \infty$

$\log(T)\quad \log(\text{delay})$

$\longleftarrow \text{Fast}$

$\longleftarrow \text{Accurate}$

$-\log(R)$
\[ \log(T) \]  
\[ \log(\text{delay}) \]  
\[ R \rightarrow \infty \]  
\[ T \rightarrow \infty \]  

\[ -\log(R) \]  

\[ \text{Turing} \]  
\[ \text{Fast} \]  
\[ \text{Robust} \]  
\[ \text{Bode} \]  
\[ \text{let } T \rightarrow \infty \text{ (differently)} \]  
\[ \text{Huge impact of delays} \]  
\[ \text{Shannon} \]  
\[ \text{Accurate} \]
\[ \log(T) \]  
\[ \log(\text{delay}) \]

- **Turing**
- **Shannon**

- **Fast**
- **Robust**

- **Previously intractable**
  - In the sense of Turing
  - NP hard, so not scalable
  - SLS changes this completely

- **Lost connection with Shannon**
- **Much more needed**

\[ R = \lambda T \]
\begin{align*}
\log(T) &\quad \log(\text{delay}) \\
R = \lambda_\alpha T &\quad \text{Equal area}
\end{align*}

Nerve SAT

\begin{align*}
R = \lambda_\alpha T \quad &\iff \quad \text{Fast} \\
-\log(R) &\iff \text{Accurate}
\end{align*}

<table>
<thead>
<tr>
<th>Nerves</th>
<th>Optic</th>
<th>Law</th>
<th>Diverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Fast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurate Inaccurate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Scalar trail and bumps
• Math is easy
• (Experiments are easy)
• Has no additional *internal* structure (e.g. within cortex)
• Beyond what is in the diagram
• What next?

• 1 dimensional
• scalar trail
• scaler bump
Flexible

Centralized

Fast

Slow

Local

Unstable

Layer decomposition

Diversity sweet spot

SLS?