The Dance of Life
Proposing a Molecular Music and Dance Project

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The Dance of Life

Towards the Performance Component for the SEAD White Paper Abstract:

“A Strategic Experiment for Promoting an SEAD Community Collaboration: A Machine for Testing Whether it is Possible to Teach Biochemistry to Non-Scientists” by Dr. Jonathan Zilberg and Dr. Barrie Kitto.

See: http://seadnetwork.wordpress.com/white-paper-abstracts/abstracts/a-strategic-experiment-for-promoting-an-sead-community-collaboration-a-machine-for-testing-whether-it-is-possible-to-teach-biochemistry-to-non-scientists/

The above draft concept, as an abstract, was subsequently expanded, adapted and published in its final form on-line as “Can Art Advance Science? A Hypothetical SEAD Experiment”.

See: http://seadnetwork.wordpress.com/white-paper-abstracts/final-white-papers/can-art-advance-science-a-hypothetical-sead-experiment/

In that context, this is an outcome of the call for participation in gauging the global scope of the emerging SEAD community through the National Science Foundation Grant, NSF Grant No. 1142510, IIS, “Human Centered Computing. Collaborative Research: EAGER Network for Science, Engineering, Arts and Design (NSEAD)
Credits

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Images of the dance Matah Ati are purposively low quality reproductions taken from the program catalog *Matah Ati* (2012) produced by Atilah Soeryadjaya with photographs by Davi Linggar.


The remaining figures and text are from outdated, undated and as of yet unidentified sources in the author’s working files.

The power point constitutes one component of The Dance of Life project which is currently in the early development phase. The performance is intended as a generative project designed to inform and highlight the proposed experimental learning machine as detailed in the on-line abstract, draft and final White Papers (the on-line links given above).
Qualifications

In order to perform this dance, neither the dancers nor the audience need to have had any previous knowledge of chemistry.

They will simply learn it through the dance, or more accurately through the training resulting in the dance, or in the case of the audience - through watching the dance repeatedly.

In adapting Matah Ati (a modern classical Javanese royal court dance re-enacting the conflict in the Mankunagaran Kingdom in the mid-18th century) to a small scale international art-science collaboration, this project seeks to significantly enhance the international cultural component of the SEAD initiative.
The purpose of this collaborative art-science dance project is to creatively convey relatively complex scientific information to audiences with no necessary knowledge of science.

It is designed to make the invisible world visible for that is what biochemistry is all about. The intention is to make that journey easier for science students and to open up the world of biochemistry to people who would otherwise never be able to understand it in the current education system.

The dance (and the embodied engineered experience to which it draws attention) is designed to scientifically and subliminally bring biochemistry to life for a general audience. It would do so unconsciously or consciously to different degrees depending on their backgrounds and capacity to engage the dance, the program notes and the accompanying digital application.

This dance and the Javanese music adapted for it, is a visual analog of the molecular and atomic processes involved in the creation of biological energy.

It is ultimately an experiment in synaesthetic learning.
The Art-Science Goals

To Embody This Knowledge of Biochemistry

To Experience it Passionately

To Convey it Effectively to the Audience

To Draw Attention to Previous Work on Sensory Pedagogy in Science Education and advance the general application of the field

To Contribute to Art-Science in the context of the SEAD community

Why Dance Chemistry?
Most people never get to study science simply because they are intimidated by it very early in the educational process.

With that in mind, the purpose of this dance performance proposal is to test whether a general audience can understand science if more artistic ways of presenting such information can be invented.

In this case, dance and music will be used to convey accurate details about a vital chemical process - The Krebs Cycle – a process through which biological energy is created.
What is the Krebs Cycle?

This is the chemical process through which energy is made from glucose as given in the equation:

Glucose + Oxygen = Carbon Dioxide + Water + Energy
Traditionally, first students have to learn the language of chemistry and then they have to understand how to use that symbolic language.

To get there is a long and difficult process.

As a consequence
Most people never learn something
As elementally important
To our modern scientific understanding of life
As the Krebs cycle.
To Start With:
This Is All The Dancers and Audience Will Need To Know

1. The world is composed of elements.

2. Each element has a different atomic weight and structure and therefore way of behaving.

3. The main atoms in this dance are carbon, hydrogen, oxygen and nitrogen as well as phosphorous

4. Atoms join together to make molecules.

5. Glucose is a molecule made of 6 carbon atoms joined together with 6 oxygen atoms and 12 hydrogen atoms.

6. Glucose is broken down in the cell to make carbon dioxide, water and energy.
Each dancer will represent one carbon atom and that atom’s behavior in the cycle.

Once again, the theory behind this proposed experiment is that basic principles and processes in biochemistry can be communicated through dance if props, motion and music are used to accurately convey visual chemical information.

In essence
This dance itself
Will reveal
The invisible world
In which biological energy
Is produced.
Glucose and The Dance of Life
Re-iterating The Goal

In this dance of the iconic biochemical process, the Krebs cycle, each of the six dancers represent one of the carbon atoms in a glucose molecule.

Each sequential dance formation and process of transformation is an embodied visual expression of what happens to one glucose molecule in the Krebs cycle and why.
Why This Dance Amongst All Others?

This is the cycle which creates biological energy on which all animal life depends. There are other cycles but this one is iconic in biological science.

Note that the dance is designed to represent this process as accurately as possible as explained in the following slides.

Each of the photographs from the adapted classical Javanese dance performance Matah Ati have been chosen as they offer particular potential for presenting and embodying the necessary biochemical information.
The relations between the dancers, the postures, hand and body movements and use of props such as rings, flags, hats or umbrellas will be critical aspect of the dance choreography.

The props will represent atoms, hydrogen ions (H+ which we term protons, hydroxyl groups (OH), oxygen (O), nitrogen (N) and phosphorous (P).

More complex organic molecules involved in the process such as ATP, NAD and FAD will be represented other props or stage set devices and special effects.

Each prop, each element of the stage design and set, each transformational movement and special effect thus conveys precise information.
Every Detail Matters

The dance gestures and props, the interactions between the dancers, the set and the props will all be designed to portray the processes involved in this cycle as usually memorized visually and verbally by science students.

The dancers will be acutely aware of the relative position of the props and the relation of each carbon atom (dancer) to each other so as to create accurate mobile impressions of each dynamic transformation.

In this way, the dancers are embodying information students imagine in their minds from diagrams and texts they have memorized.

The idea here is that embodied knowledge might in time contribute to the advancement of science through a transformational imagination in which future students are better able to conceptualize complex three-dimensional and multi-modal information in motion.
What the Dancers Will Need to Know – More Detail

Chemistry is all about the interactions between atoms and molecules

It is about the forces of attraction and repulsion between them

It is especially about protons (single positive charges, H+) and electrons (single negative charges)

It is also about the transfer and transformation of simple molecules in relation to complex molecules and how these oscillate to make energy through membrane directed transfer of protons and much more

It is about where and how they and the other atoms and charges move during these chemical reactions

Just relax and dance with me

We can get there together
Don’t Worry – Be Happy – Just Dance It

All you have to know are some very basic facts to be able to embody these relations so as to convincingly convey them through this dance.

As frightening as it may at first seem,
It is easy enough to learn
About the carbon skeletons
That comprise
Organic molecules,
To understand the nature of
Covalence bonds and resonance structures
For instance, in this case the flying hats could represent H ions as will be explained in the following slides and during the workshops for choreographing and working out the dance.
The Stage Set

The inner and main part of the stage set represents an internal cellular organelle known as a mitochondrion.

Mitochondria are double membrane packets in every cell in your body that produce energy by breaking down sugar and fat in a process called the Krebs Cycle.

This is the secret of life: The transformations and movement of molecules and atoms within and across these membranes produces energy.

This is so elemental and so important to what we know about the working of the world that everyone should know it.
What Happens in the Mitochondria: Don’t Worry, It’s Simple

Glucose is sugar. It is broken down in the cell and passed into the mitochondria where it is converted into energy (ATP) by the Krebs Cycle and a process known as the Electron Transport System. The easiest way to learn this is to dance it – or so the theory advanced here goes.
The Stage Set in More Detail

Relax, Breath, It Is Not So Hard to Understand
Hush Now - Let Me Explain
The Role of the Dancers
The first movement is to dance together in formation so as to represent the first image on the left in the figure below.

Each dancer is represented by a C. Each dancer is numbered 1 through 6 and stays in sequence at all times having a unique function as part of the whole with H, OH and O are represented by props.

The second step is for the dancers to move into the ring formation on the right. The process given below is shown in more detail in the next slide. Remember the props must be used in such a way that the exact information in these diagrams is converted into the dance.
To do so accurately, note that the first and last dancers (1 and 6) will join through an oxygen atom and that this can happen in 2 ways.

Note that the position of the -OH flag held by dancers left or right (or up and down) is important.

As you can see – you are already learning the basics of biochemistry through dance and in the explanation of the next slide we will go a bit further.
Workshop Concept Notes for Choreographers, Designers and Dancers:

**CARBON SKELETONS**
The unique role of carbon in the cell comes from its ability to form strong covalent bonds with other carbon atoms. Thus carbon atoms can join to form chains.

- also written as

**COVALENT BONDS**
A covalent bond forms when two atoms come very close together and share one or more of their electrons. In a single bond, one electron from each of the two atoms is shared; in a double bond, a total of four electrons are shared.

- Each atom forms a fixed number of covalent bonds in a defined spatial arrangement. For example, carbon forms four single bonds arranged tetrahedrally, whereas nitrogen forms three single bonds and oxygen forms two single bonds arranged as shown below.

- Double bonds exist and have a different spatial arrangement.

**HYDROCARBONS**
Carbon and hydrogen together make stable compounds called hydrocarbons. These are nonpolar, do not form hydrogen bonds, and are generally insoluble in water.

- Atoms joined by two or more covalent bonds cannot rotate freely about the bond axis. This restriction is a major influence on the three-dimensional shape of many macromolecules.

**RESONANCE AND AROMATICITY**
The carbon chain can include double bonds. If these are on alternate carbon atoms, the bonding electrons move within the molecule, stabilizing the structure by a phenomenon called resonance.

- the truth is somewhere between these two structures

When resonance occurs throughout a ring compound, an aromatic ring is generated.

- often written as
Having explained the above in the First Workshop - Here’s The Plan:

Creating Cellular Energy:
A Proposed Cyclical and Repeating Musical Drama in Three Movements
Set 1  Glycolysis
Set 2 The Krebs Cycle (TCA),
Set 3 The Electron Transport System (ETS)
It Looks Complicated - But It Really Is Not So Bad: 
Trust Me - I Am a Scientist

The following figure explains the molecular steps in which the 6 carbon glucose molecule is successively broken down into 2 three carbon molecules (called pyruvate) which then enter into the Krebs Cycle.

It might look impossible for you to understand if you have never had any science but it is actually very simple!
In the dance workshops we will explain this in a way which is simple enough for anyone without a high school science education to understand.

For now, in the following diagram sure to intimidate you, just note that a six-carbon molecule is converted into two three carbon molecules, that there are inputs and outputs such as ADP and ATP and that P (high energy phosphorous atoms) are being transferred and moved around at each step.

Each of these steps will be visually represented in the dance.

In the meantime, don’t worry what ADP and ATP is - just say it for now.

Later you’ll be introduced to the artistry and wonder of this and other relevant molecules and their molecular structure.

Believe me, not only is it beautiful, its simple.
Take It Easy - We Can Work It Out

In the next stage, a group of three dancers (representing a pyruvate molecule) looses one carbon to become two dancers and enters the Krebs cycle on joining with four other dancers.

In the first slide below only the names of each molecule is given and the number of carbon atoms.

Ignore the names for now

But remember if you can say Tyranosaurus Rex
The you can say
Phosphoenolpyruvate or Adenonsine Diphosphate
Now that the glucose molecule has been broken down into two activated pyruvate molecules, activated because they now carry a high energy phosphate, we are ready for the Krebs Cycle Itself. Each transformation, each successive group dance sequence, is represented in the 8 steps of the cycle.

From a six carbon molecule
We move to a three carbon molecule
And then to two
And it is that two carbon molecule
That enters the Krebs Cycle

The two carbon molecule joins a four carbon molecule to make six
That is then broken down first to five and then to four
to pick up another incoming two
to continue the cycle
and so it goes
round and round.
It is all about step wise transformations and Cycling around and around the same process

In the second slide below you will see the structures and The actual dance formation

In the first two of these steps There are six dancers in association Then five in the third step And thereafter there are four

Thus for the last five of the eight transformations, there are four dancers going through various transformations.

They will join with two more coming into the cycle

And so the cycle continues.
The Cycle: Forget About the Details For Now Just Note That There Are 8 steps in the Cycle
Don’t get stressed out by the comings and goings of FAD and NAD, FADH, FADH2, NADH and GTP.

I swear it’s simple:
They are just carrying stuff around,
Hydrogen ions and phosphate atoms etc.

Just dance through the sequence as we explain it!

Everything will become second nature as we practice The Dance of Life.

The idea is that in time you will develop an internalized sense of each step and the whole,
just as the audience will
and just as will those
who use the interactive dance machine
which will ideally eventually be built
to test this concept in a science or art museum.
The 8 Dance Formations (with two transitions we will explain)
Now For Set Three – The Greatest Challenge of All

The Electron Transport System, Proton Generation and the Production of ATP
In This Next and Final Repeating Stage Set

We move to the third part of this experimental art-science dance experience

Remember,

In the end
All we are doing
Is to show the amazing complexity
Of what happens
Inside the cell
As represented in the simple equation we started with:

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy (ATP)}
\]
Do Not Stress

Just keep dancing around the 8 steps of the Krebs Cycle
Eventually you will get it and how these three sets fits together
Remember - through you - so will the audience

So now for the really hard but even more interesting part

Let’s Make Some Energy
In the opening and repeated as the last slide,
I like to imagine each star
As a hydrogen ion, that is a single positive atomic charge, $H^+$, one proton.

They might look small and insignificant but they really matter. Why?

Because ultimately the chemical processes depicted in the dance so far are all for the sake of
creating a proton gradient across the inner mitochondrion membrane
and that is what produces ATP – energy –
the biological power in a high energy phosphate bond.

Showing exactly how - now that is the reason behind this dance. And remember - without this life as we know it would not exist.
The Interaction of the Dancers and the Stage Set

How Does the Dance Represent the Generation of Chemical Energy?
Its all about movement of the props across the membranes

To make **ATP**
Don’t Worry About It, Just Dance
The Stage Set, The Props and The Experience Will Do The Rest
Review: This is What You Now Know Intuitively
(source, currently unknown)

Summary

Animal cells derive energy from food in three stages. In stage 1, called digestion, proteins, polysaccharides, and fats are broken down by extracellular reactions to small molecules. In stage 2, these small molecules are degraded within cells to produce acetyl CoA and a limited amount of ATP and NADH. These are the only reactions that can yield energy in the absence of oxygen. In stage 3, the acetyl CoA molecules are degraded in mitochondria to give CO₂ and hydrogen atoms that are linked to carrier molecules such as NADH. Electrons from the hydrogen atoms are passed through a complex chain of membrane-bound carriers, finally being passed to molecular oxygen to form water. Driven by the energy released in these electron-transfer steps, protons (H⁺) are transported out of the mitochondria. The resulting electrochemical proton gradient across the inner mitochondrial membrane is harnessed to drive the synthesis of most of the cell's ATP.
Conclusion

Learning and teaching science is not easy. That is why so many students give up long before they ever get to this level of knowledge about the secret of life.

So the point of this proposed experiment is to test whether dancers who most probably have little or no such knowledge can learn such relatively advanced scientific information and whether we can thus transmit this elemental aspect of life science to others.

If this dance does eventuate it will transform the generative performance element of the proposed hypothetical biochemistry learning machine presented in the NSF SEAD White Paper from a merely theoretical collaborative proposal into a reality.
Why Generative?

Because the images, the art work, the music and special effects, will be used for designing and engineering the machine experience as a synesthetic learning experiment.

In addition, the creative outcomes will be adapted for a Digital App which will be made to convey exactly the same information as the dance. This will make The Dance of Life available on a smart phone or computer and thus extend its function as a cognitive extension learning device making it available to any student anywhere.

So Shall We Dance?
This Art-Sci collaboration is led by two co-Principal Investigators: Dr. Jonathan Zilberg (Research Associate, Department of Transtechnology, University of Plymouth) and Dr. Barrie Kitto (Professor, Department of Biochemistry, University of Texas at Austin).

Contributors to the original White Paper included Helen-Nicole Kostis (Science Visualizer & NASAViz Project Manager, NASA/GSFC). As the project develops any interested potential collaborators are invited to participate. Amy Ione (Diatrope Institute), Dr. Kevin Ahern (Department of Biochemistry, Oregon State University) and Dr. Robert Root-Bernstein (Department of Physiology, Michigan State University) have for instance agreed to serve as advisers should funding become available.

The nature and purpose of the impending performance training context is being made available here in order to secure potential funding, and partners in ASEAN and US museums and science centers for the performance of The Dance of Life and for the implementation phase of testing and documenting the pedagogical potential of the machine planned for 2014-2015.

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