

The Adventures of Miss Glucie

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A COMMON FRUSTRATION of teachers is the problem of preparing an innovative presentation of a complex topic area. The subject of bioenergetics, in particular, has always created a void between me and my students, perhaps because they could not really "see" the total process of molecular change.

I was discussing the problem with my dentist one day, contemplating trying to simplify Goodman's (1972) "Game of Metabolism," when he suggested writing a play about Miss Glucie, a glucose molecule. I liked his idea, and I decided to take it one step further by requiring my students to create and enact a play in order to understand the total process of cellular metabolism and its significance in the production of energy.

After presenting an overview of the process, I presented the students with a list of key words (see table). Students formed groups of four or five to write the play, and before beginning to write, each member of the group was required to identify each word in the list as either a process, a product (that is, a changed molecular state of glucose), a cellular structure, or an enzyme. The students were also expected to associate each word with one of the four metabolic processes.

The titles of the four acts, which corresponded to the four processes of metabolism, were provided for the students: "The Initiation" was to describe the changes in glucose that create pyruvic acid, "The

Vicious Cycle" was to represent the Krebs cycle, "The Hangover" to describe alcoholic fermentation, and "The Fatigued Muscle" to describe lactic acid fermentation.

During the writing, various reference books (BSCS 1968; Etkin 1972; Kraus 1971; Olsen 1973; and Otto and Towle 1969) were available to help the students determine the relationship of each item on the list of key words to the metabolic process being described. I reminded the students often that the evaluation of the play would be based on the frequency and accuracy of the use of key words. Each group was expected to create a four-act play with the acts corresponding to the four metabolic processes. Each act was to have an introductory narration describing the cellular setting and the molecular state of "Miss Glucie" and a concluding narration to summarize the net energy resulting from the process.

The evaluation process involved three factors. Each key word was assigned a point value. The number of key words appearing in each act and their point values were tabulated. Coherence of thoughts expressed was also evaluated but in a less quantitative way. Finally,

Key words to be used in the production of a play about metabolism.

metabolism	phosphoenol pyruvic acid
catabolism	pyruvic acid
mitochondria	2 ATPs
aerobic respiration	Krebs cycle
anaerobic respiration	citric acid
ATP	active acetic acid
ADP	carbon dioxide
glucose-6-phosphate	5-carbon compound
fructose-6-phosphate	4-carbon compound
fructose-1,6-phosphate	hydrogen proton donor
dihydroxacetone phosphate	oxygen
3-phosphoglyceraldehyde phosphate molecule	electron transport system
NAD	electrons
NADH ₂	cytochrome A, B, C
1,3-diphosphoglyceric acid	38 ATPs
3-phosphoglyceric acid	alcoholic fermentation
2-phosphoglyceric acid	ethyl alcohol
H ₂ O	lactic acid fermentation
	lactic acid



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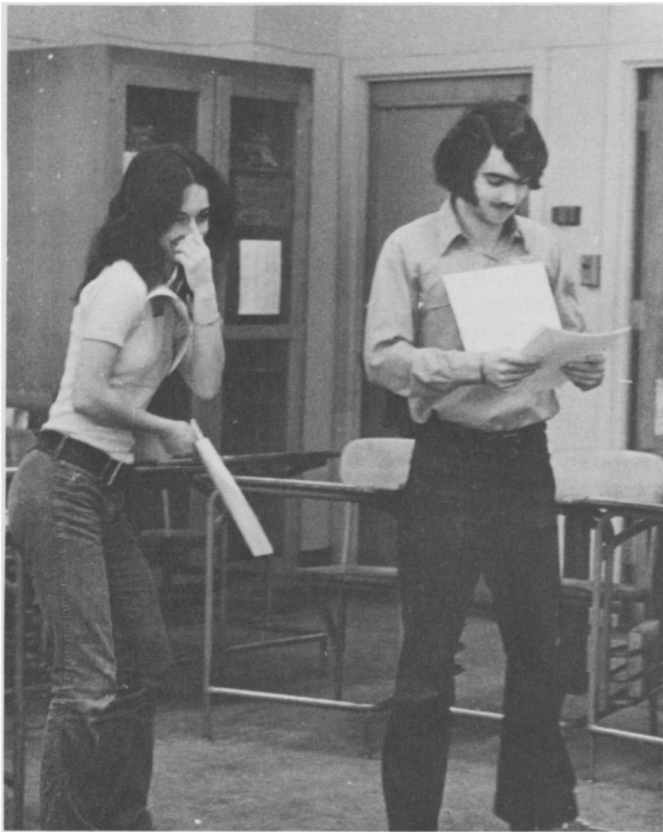
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each member of a writing team rated the others in the team using a team evaluation form (Jernigan 1972).

In acting out the plays, the goal was to have each student participate in the action. Each time a change occurred in a molecular structure, a different actor played the part of the new molecule. In a play about a process as complex as cellular metabolism, there was no shortage of roles to be played.

Other processes, such as the life cycle of viruses or the mechanism of protein synthesis, would lend themselves to the play production approach. Play



"Oh no! Now my oxygen molecule got knocked from my first carbon molecule to my second carbon molecule . . ."

writing and acting of biological processes reinforces student involvement and, thus, understanding of these processes.

The following play is an example of the actual work of the students.

The Adventures of Miss Glucie: The Roller Derby Queen

Act I. The Initiation

NARRATOR: Good evening ladies and gentlemen. Welcome to the Late Late Show. Tonight we will feature an inside look into the aerobic and anaerobic respiration of Miss Glucie, the Roller Derby Queen. We now bring you to Cristae Stadium in downtown Mitochondria City. Right now Miss Glucie and her team, the New York NADPs are battling the Kansas City NADs for the Hydrogen Cup Championship. Now let's go to the site of action.

MISS GLUCIE: I'm Miss Glucie. My team number is $C_6H_{12}O_6$. This team we're racing against is really tough. I'm beat. I need some energy.

COACH ATP: Hey Miss Glucie. I got the stuff. You can have one of my phosphates and the energy bond that comes with it, free of charge.

MISS GLUCIE: O.K. Shoot me up! Stick it right here on my sixth carbon molecule. Thanks, I needed that. It really makes me feel like Miss Glucose 6 Phosphate. But it's a shame that you're only an ADP now.

COACH ADP: That's O.K., Miss Glucose 6 Phosphate. I'd do anything for you.

(Miss Glucose 6 Phosphate goes back in the race.)

PLAYER ON OTHER TEAM: Hey, Miss Glucie, get out of my way or I'll hit you so hard it'll rearrange your atomic structure.

MISS GLUCIE 6 PHOSPHATE: Just try it!

(bam ... crash ... plop ...)

MISS GLUCIE 6 PHOSPHATE: Oh no! Now my oxygen molecule got knocked from my first carbon molecule to my second carbon molecule changing me to Franny Fructose Phosphate VI. Wow, that fall really took a lot of energy out of me. I need another phosphate fix.

ASSISTANT COACH ATP: Here, Franny. You can have my phosphate and its energy bond. But it'll cost you. This is valuable stuff ya know.

FRANNY FRUCTOSE PHOSPHATE VI: I ain't gonna pay you. I'll just take it and attach it to my first carbon molecule. *(she grabs the phosphate)* And you'll never catch me 'cause I'm changing my name to Franny Fructose Diphosphate I and VI. *(She runs, falls, and splits.)* Oh gosh! I just split into dihydroxacetone-phosphate and 3-phospho glyceraldehyde (PGAL). I better become two PGAL molecules and get back in the race. Darn, I'm only three carbons each—not much.

MISS PGAL: Gee, in this new state I'm so uncoordinated I can't even skate straight. I think I'm going to ...

(crash)

NARRATOR: Oh no! The two PGAL molecules crashed into each other. Everybody's tripping over them. What a jam-up! Let's get closer for an on the spot report.

MISS PGAL: Oh no! A PO_4 molecule just got jammed into me. It attached itself to my first carbon. Hey an NAD molecule from the other team is ripping off my best hydrogen earrings! Come on back here, you no good son-of-an-adenosine tri-phosphate. Gee, since that thief ripped off my hydrogen earrings, the only thing I have left to do is to be Miss Diphosphoglyceric Acid I and III.

COACH ADP AND ASSISTANT COACH ADP: Hey, Miss Diphosphoglyceric Acid, we want our phosphorus atoms and energy back. Hand them over or we'll kick ya off the team. We want to be ATPs again.

MISS DIPHOSPHOGLYCERIC ACID I AND III: Alright, each one of us will give ya a phosphorus atom from our first carbon atom.

(They give up their phosphorus atoms)

COACHES: Thanks. No hard feelings. You're both still great skaters even though you've converted into phosphoglyceric acid III.

MISS PHOSPHOGLYCERIC ACID #1: Gosh, golly, I don't feel too good. Let's change our atomic structure.

MISS PHOSPHOGLYCERIC ACID #2: O.K. Let's put our phosphorus atoms onto our second carbon atom making us two Miss Phosphoglyceric Acid IIs.

TWO FANS: Hey babes, we two guys would like your perty litt'l signatures in gooly blood. But since you ain't got none, how about do'in it in H_2O ?

MISS PHOSPHOGLYCERIC ACID II: Certainly. Here ya go. Have an H_2O autograph apiece. *(Each phosphoglyceric acid gives up one H_2O)* Darn! That makes us two phosphoenol pyruvic acid II molecules. Those brats shouldn't have taken those H_2O molecules.

TWO TEAM MEMBERS: We need energy. You got a spare phosphate fix by any chance?

MISS PHOSPHOENOL PYRUVIC ACID: Sure. What are friends for? Take a phosphate off our second carbon. We are now two Miss Pyruvic Acid Molecules.

TWO TEAM MEMBERS: Wow, now we ADPs have become ATPs, thanks to that energy.

NARRATOR: Miss Pyruvic Acid and the New York NADPs just won the Hydrogen Cup Championship. But if any of you intelligent persons remember, the two Miss Pyruvic Acids started as one Miss Glucie. Actually, our Miss

Glucie underwent a process called metabolism, more specifically, the initial catabolism of glucose. Basically, glucose is catabolized or broken down into two pyruvic acid molecules with the net release of 2 ATPs.

Act II. The Vicious Cycle

NARRATOR: To get back to the life history of Miss Pyruvic Acid, she had just won the Hydrogen Cup Championship. According to H-cup rules, the winners must donate two hydrogen molecules to the opposing team, in this case the NADs. Miss Pyruvic Acid is about to undergo a very vicious part of her life—aerobic respiration. To simplify things, we will just follow the events of one pyruvic acid (remember there are two). The setting is in Cristae Stadium in the town of Mitochondria just after the H-cup championship.

MISS PYRUVIC ACID: Oh gosh darn, I've been ripped off. I had to give up two hydrogen molecules to the NADs just for winning the race.

FANS: Hey, let's go get Miss Pyruvic Acid. Maybe we can rip off some carbon, hydrogen, or oxygen molecules as souvenirs.

(They chase Miss Pyruvic Acid out of the stadium)

MISS PYRUVIC ACID: I better get away from them before there's nothing left of me. Maybe I can shake them off in Mitochondria Memorial Park. Oh no, I just dropped my spare skate. By the way, my skates are made of carbon. But I don't have time to go back and get it. Hey, two oxygen atoms just picked it up. That makes carbon dioxide. Something's happening. I feel different. I've just changed to active acetic acid.

FANS: Hey, Miss Active Acetic Acid, wait!!

MISS ACTIVE ACETIC ACID: They're still following me. There's the Krebs Memorial Merry-go-round. Maybe if I get on there, they won't find me. *(She gets on the merry-go-round)*

MISS 4-CARBON COMPOUND: *(in a whisper)* Hey, Miss Active Acetic Acid—over here.

MISS ACTIVE ACETIC ACID: *(in a whisper)* Who is it?

MISS 4-CARBON COMPOUND: It's me—I'm a 4-carbon compound; join up with me and maybe they won't find you. *(They join together)*

MISS CITRIC ACID: Hey, guess what, I think that now I'm a 6-carbon molecule of citric acid. Hey, I lost another carbon skate. Two oxygens picked it up back there again. I think they like to stick together.

NAD TEAM MEMBERS: Hey, look. There's Miss Citric Acid and she's got new hydrogen earrings. Let's take them. *(An NAD takes two hydrogen earrings)*

MISS CITRIC ACID: Those creeps! Now that I lost two hydrogen earrings and a carbon skate, I feel just like an ordinary 5-carbon compound.

NARRATOR: While going around on the merry-go-round, she loses her last carbon skate and two more hydrogen earrings. Again, two oxygen molecules pick up the carbon skate.

MISS 4-CARBON COMPOUND: Now without my skates and earrings I'm just another 4-carbon compound. But I still have my spare pair of hydrogen earrings.

(bam ... crash ...)

MISS 4-CARBON COMPOUND: Wow, I just fell off my horse. Oh, my back hurts. I feel like my carbon and oxygen bonds got rearranged. That sure took some energy out of me. Hey, there goes two greedy little ADPs with my energy. That makes them two greedy ATPs. *(An NAD surrounds Miss 4-Carbon)* Help, I'm surrounded by an NAD!

NARRATOR: Well, gang, it seems that Miss 4-Carbon just lost her last, final pair of hydrogen earrings. Poor Miss 4-Carbon—she's got almost nothing left of her.

MISS 4-CARBON COMPOUND: Wow! That sure took a lot of energy out of me. Hey, there goes my energy—it just

formed a bond in an ADP molecule; but now, because of me, it's an ATP. Oh looky there. Here comes another Miss Active Acetic Acid. She's getting onto the merry-go-round. I'll go join with her. What am I doin'? I'm getting stuck on this stupid Krebs Memorial Merry-go-round.

NARRATOR: Well kiddies, that looks like the end of Miss Pyruvic Acid, Miss 5-Carbon Compound, and Miss 4 Carbon Compound. From here it's all circles for them—stuck on the Krebs Memorial Merry-go-round. Don't worry, there's still more to come. Let's follow the NADs from the other team who stole all Miss Glucie's hydrogen earrings.

(NADs are all together)

LEAD NADH₂: Hey, here we all are at Mitochondria Memorial Park, but there's almost nothing left of Miss Pyruvic Acid, at least not as we know her. And look at these hydrogen earrings; they're so cheap. Let's get rid of these stupid hydrogen protons and just keep the electrons which have all the energy.

NARRATOR: The ejected H proton donors float around the city of Mitochondria feeling very useless. The NADH₂ becomes NAD.

OTHER NAD: I don't want to carry around these stupid electrons.

ALL NADs: Yeh, let's get rid of them.

OTHER NAD: Why don't we dump these electrons on that big slide over there called Riboflavin's Electron Transport Chain.

OTHER NAD: Wow, that slide has three sections called the cytochromes B, C, and A. *(The NADs dump the electrons on the top of the electron transport)*

ALL NADs: Darn, now we're just ordinary NADs, good ole hydrogen acceptors. Let's go find some more hydrogen atoms.

CYTOCHROME B: Here comes a pair of electrons dumped by some NAD. Boy, do they have energy. I'll just swing them around a little and—WHEW!, they had so much energy that one ADP was converted to ATP. Hope the Cytochrome C has fun.

CYTOCHROME C: Thanks, Cytochrome B. Wow, these two electrons still can pack a wallop. I'll just swing them around a little and hot dog—another ADP is converted to ATP. Look out below, Cytochrome A.

CYTOCHROME A: Thanks, Cytochrome C. Hey, these dudes still have some energy. Holy Moses—another ADP was converted to ATP from their energy. Well, now these little electrons are at the bottom of the slide.

TWO PROTON, HYDROGEN DONORS: Hey, there's our electrons. Let's go join with them to be a full fledged hydrogen atom.

NARRATOR: And to conclude our story of aerobic respiration, the two hydrogen atoms linked with an oxygen, they met and lived happily ever after as a water molecule. Actually, a total of 20 electrons went down the electron transport in pairs of two, forming 10 water molecules and 30 ATPs. With the six ATPs from the Krebs cycle (three for each Pyruvic Acid) and the two ATPs from the Initiation, a total of 38 ATPs were formed. The moral of this story—a glucose a day keeps the doctor away!!

Act III. The Fatigued Muscle

NARRATOR: The setting is a street in Mitochondria, outside of Cristae Stadium. Miss Pyruvic Acid is walking to her car with NADH₂, a player from the other team. Now let's watch as Miss Pyruvic Acid undergoes anaerobic respiration by lactic acid fermentation.

NADH₂: Hey, Pyruvic, we better run. Wild fans are chasing us.

(They start running)

MISS PYRUVIC ACID: I can't make it. I'm tired.

NADH₂ I'm not gonna wait for you. I don't want those wild fans to rip me apart. Oh . . . I'm wearing hydrogen earrings. They're heavy. They're weighing me down. I can't run with them. Here, you take them. (*She dumps the earrings on Miss Pyruvic Acid*)

MISS PYRUVIC ACID: I don't want your earrings. They'll weigh me down. (*NAD runs away*) Wait for me; you can get away fast because you're just NAD now. Oh no! Those greedy fans are catching up with me. I can't find my car. Those fans are almost on top of me, and two greedy ADPs are in the crowd! They're on top of me! They're tearing up my innards. Those dirty ADPs took two whole phosphorus atoms and all the energy that goes with them. Now they're two strong ATPs. Boy, that makes me tired! I can hardly make it to the car. There it is. Almost . . . almost . . . almost . . . aahh, made it. But I've changed. Now I'm Miss Lactic Acid.

NARRATOR: Yes, our Miss Pyruvic Acid has changed into Miss Lactic Acid. She sure did lose some energy in this change, but don't worry, because two ADPs absorbed that precious, invaluable energy, and became two ATPs.

Act IV. The Hangover

NARRATOR: After the great championship at Cristae Stadium, Miss Pyruvic Acid fights off the mob of fans. She heads homeward with her hydrogen cup and a new world title. Although she doesn't know it, she is about to undergo alcoholic fermentation.

MISS PYRUVIC ACID: I can't wait till Mr. Fermentation Yeast, Ferm, gets here so I can celebrate my victorious day. (*Knock on door*) Come in, Ferm.

NADH₂: Miss Pyruvic Acid, is that you?

(*She opens the door*)

MISS PYRUVIC ACID: What are you doing here? Get out of here before I break your head.

NADH₂: Hold your cool, will ya! I brought back your crummy hydrogen earrings that I ripped off earlier. When I got home I realized that they weren't worth wasting my time for.

MISS PYRUVIC ACID: You creep. Without these earrings you're nothing but a stupid NAD. How could you possibly give them up?

NAD: Let's just say I'm a generous person.

MISS PYRUVIC ACID: Get out of my apartment. I don't want to see that baboon of a face ever again.

(*NAD leaves and Mr. Fermentation Yeast enters*)

FERM: What's all the racket?

MISS PYRUVIC ACID: Nothing much. I'll tell you on the way to the party. Come on before we're late.

(*They go to the party*)

FRIEND: Hey man! Haven't seen ya in a long time. What's happening?

FERM: Nothing. Same old drag.

FRIEND: Hey who's the little lady?

FERM: My girlfriend, Pyruvic.

FRIEND: Hey sweets, wanna drink?

MISS PYRUVIC ACID: I have one.

FRIEND: Have another one. A little alcohol never hurts anyone. Not even me. How about you, Ferm?

FERM: Yeah, I'll have another one.

ANOTHER FRIEND: Hello Mr. Yeast. How are you tonight?

FERM: Living.

ANOTHER FRIEND: Well, I haven't seen you two in a while. How have you been?

FERM: We're fine. (*They get drunk and leave the party*)

MISS PYRUVIC ACID: Let's go to my apartment.

(*They go to Miss Pyruvic Acid's apartment.
She gets pregnant!! Nine months pass.
They're sitting in Miss Pyruvic Acid's apartment.*)

MISS PYRUVIC ACID: Ferm, I think I'm due.

FERM: Come on. I'll call the doctor and take you to the hospital.

(*Later in the hospital*)

DOCTOR: Congratulations, Mr. Yeast. You have a new baby boy. Miss Pyruvic has named him CO₂.

FERM: When can I see him? How is Miss Pyruvic? Does he look like me?

DOCTOR: Hold on, Ferm. Your friend Pyruvic is fine. The nurse will bring the baby out in a minute. But, Ferm, I must talk to you.

FERM: What is it, Doc. Something's wrong?

DOCTOR: There is a law in Mitochondria that you have to be married or give up the baby for adoption. There is also another law that states that you must donate some money to charity. And get this, the only money accepted is energy! So, is your wife planning on getting married and giving some energy to the ADP Commonwealth of Mitochondria City Charity Fund?

FERM: Oh yes, we'll certainly do both as soon as possible.

(*A week later*)

PRIEST: Do you, Mr. Fermentation Yeast, take this girl to be your lawful wedded wife?

FERM: I do.

PRIEST: And do you, Miss Pyruvic Acid, agree to donate two phosphorus atoms and some energy to the ADP Commonwealth of Mitochondria City Charity Fund to help two little ADPs become strong ATPs?

MISS PYRUVIC ACID: Yes, I certainly do!

PRIEST: Then do you take this man to be your lawful wedded husband?

MISS PYRUVIC ACID: I do.

PRIEST: Well then, my dear children of the anaerobic respiration, I now pronounce you Mr. and Mrs. Ethyl Alcohol!

NARRATOR: As a result of this bonding, carbon dioxide, two ATPs, and ethyl alcohol was produced.

The End

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