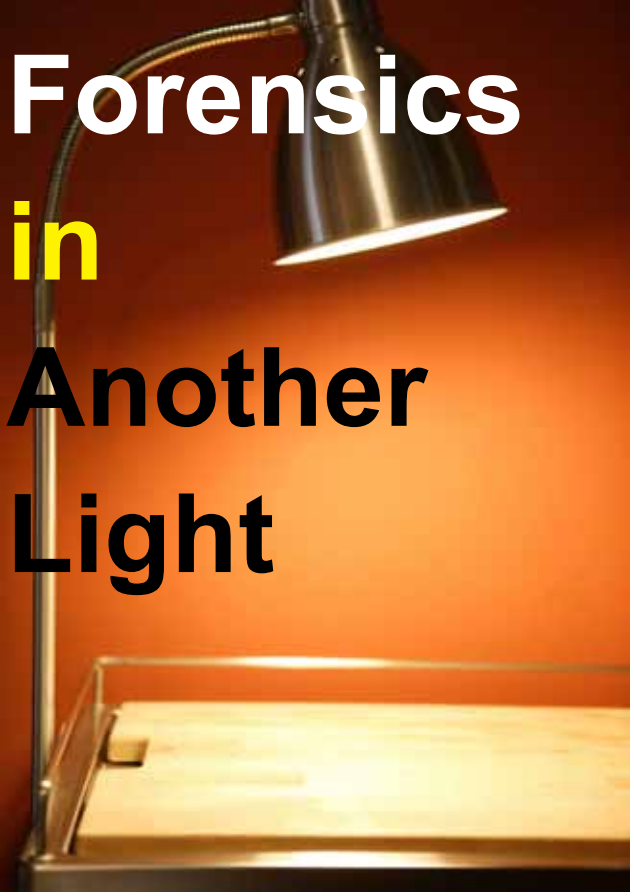

Using Timelines to Learn Forensics

By Neal Haskell, Ph.D.

The life cycle of insects have the wonderful capacity to be utterly predictable. So, when a young lady turns up dead, covered in maggots, it's not rocket science to figure out how long her body has been where it was found.

The activity on the next several pages will give your students a taste of the deductive reasoning all forensic entomologists must employ to do their job, but without the smell of rotting flesh or the sight of happy, squirming maggots. Sometimes, we all have to make sacrifices.

The students should receive copies of all sheets of the exercise with the exception of the one on page 29. This page contains the answers to the worksheet the students will complete on page 28. They'll write out their answers on page 31. A guide to working through the calculations is on age 32, as is the solution.

This activity can be done by students working alone, in pairs, or threes.

Facts and Hints:

Blow flies find and colonize dead bodies very quickly after death if environmental conditions are favorable. Some species can be found on a body within seconds to minutes after death, and eggs can be found within the first hour of death if it is warm or hot. However, there is a possibility of a delay in the time from death to the first eggs which are deposited. This time can be a few minutes when it is hot to a few days if it is cold.

There is usually one or two very early species of blow flies which are the very first blow flies to find a body. The egg laying (oviposition) activity will then stimulate or attract other blow flies to come to this fresh food source to lay additional eggs. These blow flies, in turn, attract many (hundreds) more to come and lay eggs on the body. This is known as oviposition frenzy. Therefore, we will have different ages of eggs, larvae, or puparia associated with any corpse. The key to a precise estimate of the time of death is to recognize which of the samples collected is the oldest and use those specimens from that sample to make the final determination as to how long the body has been dead. Specimens from younger life stages can provide a minimum time of death, but your estimate will be short of the total time the victim has been dead.

When the blow flies colonize a body the preferred site for colonization is the face (mouth, nose, and eyes). Sites on the body where there has been a wound are also places where initial or early colonization will occur. However, the location where the oldest specimens are usually found is the head or face area.

Blow flies do not fly and oviposite (lay eggs) at night.

KAA is a protein fixative and will also kill the fly larvae. It is comprised of 1 part kerosene, 2 parts glacial acetic acid, and 8 parts 95% ETOH (ethyl alcohol). When collecting from a death scene, the larvae (maggots) are placed into this solution for a few hours to a few days, then transferred into 95% ETOH for permanent storage (preservation can be for decades).

The maggot motel (fly rearing container) is usually a pint sized container with saw dust, sand or vermiculite in the bottom. An aluminum foil pouch is made in which is placed ca. (approximately) 2-3 oz. of meat product (beef liver is best, but other meat products will work) with 30 – 40 maggots placed on the liver. This pouch is then placed into the pint sized container and the larvae allowed to mature from feeding maggots to migrating maggots to puparia (the cocoon stage) to the emerging adults. These rearing containers are checked daily, and if newly hatched adults are found, they are taken from the rearing containers, placed into a small cage or net and placed into a freezer for 15 to 20 minutes to kill them. Once they are dead, they can be pinned after a few minutes or placed into permanent storage vials with 95% ETOH in the vials. They are then later identified to species and thus they confirm what species of blow flies the larvae were.

Conversion to Celsius from Fahrenheit: $C = 0.5556(F - 32)$

Degree Day and Accumulated Degree Day (DD and ADD) in Celsius Temperature (10 is the base temperature in this case)
DD = (Maximum + Minimum)/2 – base temp Ex: 13 = (26 + 20)/2 - 10

Add each days accumulation to the previous total. Ex: DD1+DD2+DD3+DDn = total duration ADD
$ADD = DD_1 + DD_2 + DD_3 + DD_n$ Ex: 25 = 8 + 4 + 3 + 10

DD and ADD must be calculated in ºC

DD= degree day
ADD= accumulated degree day
DD-B10 = degree day with a base of 10°C lower limit threshold
ADD-B10 = accumulated degree day with a base of 10°C lower limit threshold
DH B-10 = degree hour with a base of 10°C lower limit threshold
ADH-B10 = accumulated degree hour with a base of 10°C lower limit threshold

You cannot calculate degree days or degree hours without a lower limit threshold, which is a temperature below which growth and development ceases. If this limit is reached, then the value for anything below this must be a value of 0 and cannot be a negative number. If you use a negative number and add them that implies the organism is actually growing younger!

Investigation Into the Death of Candi Roberts (Timeline)

Death Investigation of Candi Roberts
Goodtown, Indiana, Wonder County. Located in northeast Indiana.
Remains Found: July 28, 2014, at 3:00 PM.
Autopsy Conducted: July 29,2014, 9:00 AM
Body Identified: Candi Roberts

July 19, 2014 (6:00PM)

Candi had a date with Jerry Higgins and went to a movie.

July 20, 2014 (10:15PM)

Friends of Candi, Kelly Bing and Sarah Smiley, went to one of the local bars in town with Candi. Candi stayed with some guys who were trying to sell the girls some meth. The other two girls, Kelly and Sarah, left the bar at about 1:30AM

July 23, 2014 (4:00PM)

Kelly Bing had not heard from Candi so she called her cell phone but received no answer.

July 24, 2014 (10:00PM)

When Candi's roommate had not seen or heard from Candi since she left with the two girls to go to the bar on the night of the 23rd, the roommate called police and reported her missing.

July 28, 2014 (3:00PM)

Candi's body was found in a wooded area known as Randall's Woods. She was laying on her right side with three gunshot wounds to the side of her head. Decomposition was extensive with here head mostly skeltonized and large maggot mass moving into the upper torso of her body. No other wounds were seen at the time. Insect collections were made before body recovery at the scene. It was observed that maggots were beginning to leave the remains and wander into the surrounding forest leaf litter and underbrush. They were found about 8 to 10 feet from the remains in a southwesterly direction.

July 29, 2014 (4:20 PM) Police Interview

At this time Milton Henry stated to police that he and Candi talked briefly about the money she owed him when he saw her at the park on July 25, 2014 (7:15PM).

Candi Roberts
2014 - 0728

Table 1

Student Data Table

Daily Max/Min Temperatures from July 28, 2014 to July 15, 2014
NWS Station Goodtown, Indiana

	Temperatures		Daily	Temperatures				
Date	Max °F	Min °F	Mean °F	Max °C	Min °C	DD-B10	ADD-B10	Notes
7/28/04	83	74						body found
7/27/04	88	76						
7/26/04	94	74						
7/25/04	92	77						friend talked with her
7/24/04	89	69						
7/23/04	87	63						
7/22/04	84	66						
7/21/04	84	65						
7/20/04	83	62						out with friends
7/19/04	88	65						
7/18/04	85	61						
7/17/04	80	71						
7/16/04	79	63						
7/15/04	75	58						

Conversion -- Celsius to Fahrenheit C = 0.5556 (F-32)

DD and ADD must be calculated in ºC
Use DD = (Max + Min)/2 - 10
Add each days accumulation to the previous total.

10°C is the base temperature in this case
DD1+DD2+DD3+DDn = total duration ADD

DD= degree day
ADD= accumulated degree day
DD-B10 = degree day with a base of 10°C lower limit threshold
ADD-B10 = accumulated degree day with a base of 10°C lower limit threshold
DH B-10 = degree hour with a base of 10°C lower limit threshold
ADH-B10 = accumulated degree hour with a base of 10°C lower limit threshold

You cannot calculate degree days or degree hours without a lower limit threshold, which is a temperature below which growth and development ceases. If this limit is reached, then the value for anything below this must be a value of 0 and cannot be a negative number. If you use a negative number and add them that implies the organism is actually growing younger!

Table 1 Instructor

Candi Roberts
2014 -- 0728

Daily Max/Min Temperatures from July 28, 2014 to July 15, 2014
NWS Station Goodtown, Indiana

Date	Temperatures Max °F	Min °F	Daily Mean °F	Temperatures Max °C	Min °C	DD-B10	ADD-B10	Notes:
7/28/14	83	74	78.5	28.3	23.3	15.8	15.8	body found 1500hrs
7/27/14	88	76	82.0	31.1	24.4	17.8	33.6	
7/26/14	94	74	84.0	34.4	23.3	18.9	52.5	
7/25/14	92	77	84.5	33.3	25.0	19.2	71.6	friend talked with her 1900hrs
7/24/14	89	69	79.0	31.7	20.6	16.1	87.8	
7/23/14	87	63	75.0	30.6	17.2	13.9	101.6	
7/22/14	84	66	75.0	28.9	18.9	13.9	115.5	
7/21/14	84	65	74.5	28.9	18.3	13.6	129.1	
7/20/14	83	62	72.5	28.3	16.7	12.5	141.6	out with friends
7/19/14	88	65	76.5	31.1	18.3	14.7	156.4	
7/18/14	85	61	73.0	29.4	16.1	12.8	169.2	
7/17/14	80	71	75.5	26.7	21.7	14.2	183.3	
7/16/14	79	63	71.0	26.1	17.2	11.7	195.0	
7/15/14	75	58	66.5	23.9	14.4	9.2	204.2	

Table 2 DD-B10 ***From Kamal 1958***

Phormia regina
Constant temperature reading
26.7°C

Stages	Time(hrs)	S (hrs)	DH-B10	ADH-B10	DD-B10	ADD-B10
Eggs	16	16	267.2	267.2	11.1	11.1
1st Instar	18	34	300.6	567.8	12.5	23.7
2nd Instar	11	45	183.7	751.5	7.7	31.3
3rd Instar	36	81	601.2	1352.7	25.1	56.4
Prepupa (migration)	84	165	1402.8	2755.5	58.5	114.8
Pupa	144	309	2404.8	5160.3	100.2	215.0
Total	309				215.0	

Lucilia sericata
Constant temperature rearing 26.7°C

Stages	Time(hrs)	S (hrs)	DH-B10	ADH-B10	DD-B10	ADD-B10
Eggs	18	18	300.6	300.6	12.5	12.5
1st Instar	20	38	334.0	634.6	13.9	26.4
2nd Instar	12	50	200.4	835.0	8.4	34.8
3rd Instar	40	90	668.0	1503.0	27.8	62.6
Prepupa (migration)	90	180	1503.0	3006.0	62.6	125.3
Pupa	168	348	2805.6	5811.6	116.9	242.2
Total	348				242.2	

Calliphora vicina
Constant temperature rearing 26.7°C

Stages	Time(hrs)	S(hrs)	DH-B10	ADH-B10	DD-B10	ADD-B10
Eggs	24	24	400.8	400.8	16.7	16.7
1st Instar	24	48	400.8	801.6	16.7	33.4
2nd Instar	20	68	334.0	1135.6	13.9	47.3
3rd Instar	48	116	801.6	1937.2	33.4	80.7
Prepupa (Migration)	128	244	2137.6	4074.8	89.1	169.8
Pupa	264	508	4408.8	8483.6	183.7	353.5
Total	508				353.5	

Forensic Entomology Investigation of Candi Roberts

Insect Evidence Recovered from the Body at the Scene

Temperature — from climatological data sheet

RESULTS OF EXAMINATION

Sample #1 – 7/28/14 (1530hrs) – larvae from head area–at scene; preserved KAA
(36) – mature 3rd stage larvae -- Diptera: Calliphoridae, *Lucilia sericata*
(15) – 3rd stage larvae -- Diptera: Calliphoridae, *Phormia regina*

Sample # 2 – 7/28/14 (1530hrs) – larvae from head area–at scene; live into maggot motel –at scene; with liver
(12) – adult fly -- Diptera: Calliphoridae, *Lucilia sericata* reared 8/5/14
(9) – adult flies -- Diptera: Calliphoridae, *Phormia regina* reared 8/10/14

Sample #3 – 7/28/14 (1600hrs) – larvae from 5 feet north of head –at scene; preserved KAA
(14) – migrating larvae -- Diptera: Calliphoridae, *Lucilia sericata*

Sample #4 – 7/28/14 (1606hrs) – larvae from 5 feet north of head –at scene -- live into maggot motels with liver.
(10) – adult flies -- Diptera: Calliphoridae, *Lucilia sericata* reared 8/3/14

Based on the above findings from the insect evidence, you, as a forensic entomologist, must provide answers to the coroner and the police as to the happenings of the case.

Name(s)_____ Date_____

Your conclusion (and reasoning):

Candi Roberts Murder Investigation Solution

There are essentially three elements in solving a time since death (postmortem interval) cases using blow fly larvae (the most often used insect group in forensic entomology, also eggs and puparia). This is accomplished in an orderly manner moving from data set to data set.

First, using larvae (usually the largest) within a stage (1st, 2nd, 3rd) determine what these oldest larvae are (early, mid, mature larvae of each stage, usually relative length to girth).

Second, identify the species which comprise the sample (there could be multiple species). This may be accomplished through morphological characters of the stages of larvae, or maybe not. Some larval characteristics may not be distinguishable among/between some species, yet others are very obvious. This then necessitates rearing the larvae to the adult stage which is then definitive and also serves as a check for larval identification.

Third, once the species and the oldest life stage of that species present is determined, go to the appropriate growth and development tables provided for that species. I have used data from the Kamal study (1958) which has worked in cases for over 50 years with hundreds of cases being analyzed (Table 2). These data are based upon mode of the distribution and in my opinion are extremely reliable, unlike some more recent studies focusing on the minimum time duration or research methods of establishing the data which are not fully explained in the research papers. With Table 2 we are given the mode of the distribution which provides data for the most prevalent or most frequent occurrence of the data set. Not all specimens have moulted to the next stage (eg. 2nds to 3rds), thus we are in the early portion of the change from 2nd to 3rds for example. This is the ADD-B10 value that is provided for each stage interval. Looking at the table for *Lucilia sericata* we find that for 3rd instar (stage) larvae it would take approximately 62 ADDs to reach into the mode of that distribution. However, if we were to find mature 3rd instar larvae, we are obviously beyond this value and require more energy units to reach this growth level. With our case, we do see mature 3rd instar larvae, but in another sample we have recovered a few migrating larvae of *L. sericata* and these would be even older than the mature 3rds. Therefore, since we do not have many migrating 3rds, we will use the presented data for the migrating thirds mode (125ADDs). This would be the outer value of the growth and development and we really need to provide a range of values to allow for biological variability. We could then start with halfway between the 3rd stage data and the migrating data which would be somewhere in the 95-100ADD-B10, as a minimum, out to the 125 ADD-B10 value, for our maximum.

Fourth, we now consult Table 1 with our daily energy unit accumulations. We are looking for energy unit values between approximately 100ADD-B10 and 125ADD-B10. This range occurred between the 23rd and 21st. However, these values are from midnight to midnight with a portion of the data for 23rd happening after darkness so the flies could not have laid eggs at that time period, so we go back to daylight hours of the day before, that being 22nd. Also she was last known alive at (2215hrs) on the 20th. Likewise, this is during darkness and blow flies are not active at night. Therefore any colonization would have occurred following sunrise on the 21st. Thus, insect colonization and death would have been between sunrise of the 21st and no later than sunset of the 22nd. The person who said they talked with her on the 26th is either mistaken or lying.

Another major variable factor, which is essential, is the environmental factors of a case, which were not brought into this exercise. Solar radiation, shading, close proximity to a stream or river or other bodies of water, burial, and a host of other variable can be taken into consideration and evaluated for their inputs into the degree day calculations and estimates.

I hope you have enjoyed this exercise and the challenges concerning the variability with which forensic entomologist's are faced with