Time of death: how a post-mortem interval is estimated

Method, formulas, worked example, practice problems, then the lab. No calibration set for this module.

CLAIM CEILING. READ THIS FIRST.

- **Polygraph.** It records breathing and heart rate. A change in either one is a physiological response. It is not a measurement of lying, and nothing in this unit produces a deception call.
- **Hair.** Microscopic similarity can support consistency or support exclusion. It cannot identify one person.
- **Fingerprint.** Pattern class can narrow a field or exclude a person. By itself it cannot name a source, and it never says when or why a finger touched something.
- **Timeline.** A scheduled event is not proof the person was there. Time of death is not established in the early case evidence.

Anna Garcia Forensic Methods Unit. Background module. No graded exercise depends on this card, and every number inside it is invented practice data.

The unit keeps telling you that time of death is not established in the early case evidence. This card is where you find out how it would be established, what it would have cost to establish it, and why the honest answer is always a range.

Two temperature units live on this card. Body cooling work is in degrees Fahrenheit, because the Glaister equation is written in Fahrenheit. Insect work is in degrees Celsius, because insect development tables are written in Celsius. Write the unit next to every number you record. Mixing them quietly is the fastest way to a confident wrong answer.

To convert: °C = (°F − 32) × 5/9, and °F = (°C × 9/5) + 32.

What this analysis can and cannot tell you

- **It gives you a post-mortem interval as a range, and the range is wide.** The post-mortem interval, or PMI, is the time between death and the moment you took your measurements. Every method on this card produces a span of hours with real uncertainty inside it. Reporting the middle of that span as the answer throws away the part of the result that was honest.
- **It cannot give you a clock time.** You measure an interval. Turning that interval into a time on a clock requires a second thing you also measured, which is the time you took the reading. Write that time down at the scene. If you did not write it down, the interval has nothing to attach to and the whole analysis is worthless.
- **Every method degrades as the interval lengthens.** A body cools until it reaches the temperature of its surroundings, and after that the thermometer stops telling you anything new. Stiffness comes and then goes, so the same observation can mean two different windows. Insect development runs through stages that get longer and harder to pin down. The first day is the strongest day, and every day after that the range gets wider.

- **None of it can be done from a photograph after the fact.** These methods need a core temperature taken at the scene, a temperature log for the scene, and insects collected and preserved before anyone moves the body. Unless the case file hands you a core body temperature, a rigor and lividity record, and a temperature history for the location, no post-mortem interval can be computed from it. That is what "time of death is not established" means. The sentence describes what was recorded at the scene. It makes no claim that the interval was impossible to measure.

The three clocks

Three separate processes start in a body at death, and they run on three separate kinds of physics and chemistry.

- **Algor mortis** is cooling. A body stops making heat and starts losing it to whatever surrounds it. This clock is driven by heat transfer.
- **Rigor mortis** is stiffening. Muscle runs out of ATP, the molecule a contracted muscle needs in order to let go, so the muscle locks. Later, the muscle tissue itself begins to break down and the stiffness fades. This clock is driven by chemistry inside cells.
- **Livor mortis** is blood settling. Blood is no longer pumped, so gravity pulls it to the lowest parts of the body and stains them. Early on, pressing the skin pushes the blood aside and the spot goes pale. Later it does not. This clock is driven by gravity and by blood thickening.

A fourth clock runs outside the body. Blowflies find dead tissue and lay eggs on it, usually at the nose, mouth, eyes, or any wound. Those eggs hatch and the larvae grow through named stages at a speed set almost entirely by temperature. That is insect colonisation, and it is a clock made of a completely different organism.

Why more than one matters. Each clock has its own way of being wrong. A warm room slows cooling. A warm room speeds up stiffening. Those are the same room and opposite errors. If you run only the cooling clock, a warm room quietly shortens your answer and nothing on your sheet warns you. If you run both, the two clocks pull apart and the gap between them is a signal that something about the environment is doing work you have not accounted for. Methods that fail differently do not stack their errors, so their overlap is more trustworthy than either one alone.

They can and do disagree. That is normal. A disagreement narrows your answer if the ranges still overlap, and it tells you an assumption is broken if they do not. Either way it is information you write down.

Teaching brackets for rigor and lividity

These brackets are the version this unit uses. They come from the ranges given in standard forensic pathology texts, and those texts do not all agree with each other. Temperature moves every one of these numbers, sometimes by many hours. Use them as a coarse bracket, never as a measurement.

What you feel or see	Bracket this unit uses (hours since death)
No stiffness anywhere	0 to 4, **or** more than 36
Stiffness starting, felt first in jaw, neck, fingers	2 to 8
Stiff and firm in every joint you test, no softening	6 to 30

What you feel or see	Bracket this unit uses (hours since death)
Stiffness fading, joints move again with effort	24 to 48
No lividity visible	0 to 2
Lividity visible and it goes pale under thumb pressure	1 to 12
Lividity visible and it stays coloured under thumb pressure	8 or more

Read the first row again. A body with no stiffness at all is either very early or very late. One observation, two windows, and no way to tell them apart from stiffness alone. This is exactly why you never run one clock by itself.

Lividity's most useful job is not timing. If the stained areas do not match the position the body was found in, the body was moved after death, and every assumption you were about to make about the scene's temperature history just became unsafe.

The formulas, explained

1. The Glaister equation, for body cooling

> PMI (hours) ≈ (98.4 − rectal temperature in °F) / 1.5

What each part means.

- **PMI** is the post-mortem interval in hours, counted back from the moment you took the reading.
- **98.4** is the assumed core body temperature at the moment of death, in °F. It is a number somebody chose as an average living person. It is not measured from the body in front of you and it cannot be.
- **Rectal temperature in °F** is the core temperature you measured. It is taken rectally because that reads the deep core. A skin or forehead reading tracks the room, not the core, and is useless for this.
- **1.5** is the assumed average cooling rate in °F per hour. It is also a number somebody chose.

What it assumes. That this person started at 98.4 °F. That the body lost heat at a steady 1.5 °F every hour from the moment of death onward. That the surroundings were ordinary still indoor air at ordinary indoor temperature.

When it breaks.

- **In the first two hours.** A body barely cools at first. The core is insulated by everything around it and takes a while to start dropping. During that plateau the real cooling rate is far below 1.5 °F per hour, so the equation reports fewer hours than actually passed.
- **After roughly 24 hours.** The body reaches the temperature of its surroundings and stops falling. Do the arithmetic on a 70 °F room. The largest drop the equation can ever see is 98.4 − 70 = 28.4 °F, and 28.4 / 1.5 = 18.9 hours. In that room this equation can never report more than about 19 hours, no matter how long the person has been dead. It has run out of range and it will not tell you so.
- **In water, in wind, in direct sun, in a hot room, in a freezing room.** All of these change the real cooling rate away from 1.5, and the equation has no place to put that information.

- **If the person had a fever or was cold before death.** Then 98.4 is the wrong starting number and every hour that follows is wrong with it.

2. Newton's law of cooling, the honest version

> T(t) = T_ambient + (T_0 − T_ambient) · e ^ (−kt)

What each part means.

- **T(t)** is the body's core temperature at time t after death, in °C or °F. Pick one unit and stay in it for the whole calculation.
- **T_ambient** is the temperature of the surroundings, same unit, assumed to hold steady.
- **T_0** is the body's core temperature at the moment of death, same unit.
- **t** is the time since death, in hours.
- **k** is the cooling constant, in units of 1 per hour. A bigger k means faster cooling. It depends on body mass, on clothing, and on how fast the surrounding air or water moves. You fit k to the scene. There is no table you look it up in.
- **e** is about 2.718, the base of natural logarithms.

What the shape of it tells you. The term (T_0 − T_ambient) is how far the body has to fall. The exponential shrinks that gap by the same fraction every hour. So the body loses a lot of degrees in the first hour and fewer in every hour after that. Cooling is fast at first and slows down. The single average rate of 1.5 °F per hour in the Glaister equation is a straight line drawn through a curve. It sits above the curve early and below it late, which is another way of saying the same thing you already read: the estimate is worst at the two ends.

To get time out of this equation you rearrange it:

> t = −(1 / k) · ln[(T(t) − T_ambient) / (T_0 − T_ambient)]

You are not asked to compute that by hand anywhere in this unit. It is printed here so you can see that the time falls out of the equation rather than out of a lookup table.

What it assumes. That ambient temperature stayed constant. That the whole body is one uniform temperature. That no heat is produced after death. That there is no plateau. That nothing outside is adding heat.

When it breaks. Outdoors, where ambient swings twenty degrees between the afternoon and the small hours, so T_ambient is not one number. In sun, wind, or water. In the first hours, where the plateau means the curve does not start where the equation says it starts. And once the body gets close to ambient, where the top of that fraction becomes a small number and a measurement error of half a degree turns into an error of many hours.

What real examiners use. A corrected version of this curve that adds a plateau term and correction factors for body mass and clothing, published by Henssge and worked as a nomogram. Henssge and Madea report a 95 percent confidence band of about ±2.8 hours for that nomogram under standard conditions, widening substantially once correction factors are applied (Henssge-2004). That figure belongs to that method under those conditions. It does not describe the simple Glaister estimate you will be making, which is looser.

3. Accumulated Degree Hours, for insect evidence

> ADH = Σ (T_hourly − T_base) × hours

What each part means.

- **ADH** is accumulated degree hours, in degree-hours. It is a stock of heat that builds up over time, the way a bank balance builds up from deposits.
- **T_hourly** is the average temperature during one hour, in °C.
- **T_base** is the base temperature, in °C. It is the temperature below which that species stops developing entirely. It is species-specific and comes from published development studies, not from a general rule.
- **hours** is the length of each block. For an hourly log it is 1.
- **Σ** means add up every block.

Some tables are written in accumulated degree days instead. ADD = ADH / 24.

Why this works as a clock. An insect at a given temperature develops at a given speed. Warmer means faster. Colder means slower. A blowfly needs roughly a fixed amount of accumulated heat to get from egg to any named stage, and that amount holds whether the heat arrived fast over one warm day or slowly over three cool ones. So if you know the species, know the stage the larvae have reached, and have an hour-by-hour temperature log, you can add hours backwards until the total reaches the amount that stage requires. The hour where you cross the requirement is the hour the eggs were laid.

What it assumes. That you identified the species correctly. That the T_base and the required ADH you used came from a table for that exact species. That the temperature the log recorded is the temperature the insects actually experienced. That development speed rises in a straight line above T_base. That an hour below T_base contributes zero, never a negative number.

When it breaks.

- **Wrong species, or no species.** The constants change completely between species. Without an identification the requirement is a guess wearing a decimal point.
- **The log is not the body's temperature.** A weather station five miles away, at a different height, over a different surface, in different shade, is not the microclimate on the body. Sun on a body raises it. So does a large mass of feeding larvae, which generates its own heat and can run well above the air around it.
- **Temperatures near or below T_base.** The straight-line assumption is at its worst there.
- **Very high temperatures.** Above a species' upper limit, heat slows development or kills the larvae. The equation does not know that and keeps adding.
- **The clock started late.** This is the big one, and it gets its own paragraph in two sections below. ADH counts from egg-laying, which is not the same moment as death.

Worked example, done all the way through

This is **PRACTICE-TOD-1**. Every number in it is invented for practice. It is not the Anna Garcia case and none of it transfers to the Anna Garcia case.

The practice scene. A body is found outdoors, in continuous shade behind a building, at 6:00 p.m. The body is clothed in a shirt and jeans, lying on dry concrete. There is no standing water. The air is still. Adult flies are present and a patch of eggs plus newly hatched small larvae sits at the nose. The practice species is called PB-1. Practice sunrise that day was 6:30 a.m.

The practice development table for PB-1 says: T_base is 10 °C, and reaching the observed stage requires 140 to 170 accumulated degree hours above 10 °C, counted from the moment the eggs were laid.

1. Record the scene before you touch the body

Put a thermometer at the same height as the body, in the same shade, and read it. Write the number and the clock time. Photograph the insects where they sit, before anything is collected. Write down what the body is wearing, what it is lying on, whether anything covers it, whether any air is moving, and whether the sun has been on it at any point today. Get the local hourly temperature record for this location, or start logging one now if none exists.

You are done with this step when: every field on your scene sheet holds either a number with its unit or the words "not recorded," and each entry carries the clock time you wrote it.

In this practice scene: shade thermometer reads 24 °C at 6:00 p.m. Still air. Dry concrete. Shirt and jeans, no covering. No sun exposure at any point. A 24-hour hourly log is available for this shaded spot.

2. Take and log the core temperature

Take a rectal temperature. Write the reading and the exact clock time on the same line, because the interval you calculate will be counted back from that clock time and nothing else.

You are done with this step when: one line on your sheet holds a rectal temperature in °F and the clock time it was taken.

In this practice scene: **86.4 °F at 6:00 p.m.**

3. Test rigor and lividity, and write what you felt

Try the jaw, the neck, the fingers, the elbows, the shoulders, the hips, and the knees. For each one write moves freely, moves with effort, or locked. Then find the lowest parts of the body, look for lividity, and press one stained area with your thumb for ten seconds. Write whether it went pale or stayed coloured. Write whether the stained areas match the position the body is lying in.

Write what you felt and saw. Do not write what you think it means. The meaning is a separate step and mixing the two is how an observation gets bent toward the answer you already like.

You are done with this step when: every joint you tested has a written result, and lividity is written down as pale-under-pressure or fixed, with its position on the body noted.

In this practice scene: every joint tested is locked and firm. Nothing is softening. Lividity is present on the back and the backs of the legs, stays coloured under thumb pressure, and matches the position the body is lying in.

4. Collect and record the insect evidence

Record what stage you can see and where on the body it sits. Collect two samples. One goes straight into preservative so a specialist can identify the species from what was actually there at this hour. The other goes in alive so it can be reared out, because some species can only be identified as adults. Label both with the location on the body, the date, and the time.

You are done with this step when: the stage and its location are written down, and two labelled samples exist, one preserved and one live.

In this practice scene: eggs plus newly hatched first-stage larvae at the nose. Both samples collected and labelled. The specialist confirms PB-1.

5. Run the Glaister equation, then turn the number into a range

Do the arithmetic once for the point estimate. Then do it twice more, once with the assumptions pushed as far as they go in each direction, because the two constants in that equation are where the uncertainty lives. This unit uses a starting temperature of 97.4 to 99.4 °F and a cooling rate of 1.2 to 1.8 °F per hour.

You are done with this step when: three numbers sit on your sheet, the point estimate, the fast-cooling end, and the slow-cooling end.

In this practice scene:

Point estimate: (98.4 − 86.4) / 1.5 = 12.0 / 1.5 = **8.0 hours**

Fastest cooling, lowest start: (97.4 − 86.4) / 1.8 = 11.0 / 1.8 = **6.1 hours**

Slowest cooling, highest start: (99.4 − 86.4) / 1.2 = 13.0 / 1.2 = **10.8 hours**

Cooling range: **6.1 to 10.8 hours**, which counted back from 6:00 p.m. is death between about 7:10 a.m. and 11:55 a.m.

6. Convert the rigor observation into a bracket

Read your written observation off the sheet, find the matching row in the teaching bracket table, and copy the bracket across. Then write one sentence saying whether that bracket narrows anything you already have.

You are done with this step when: a bracket in hours sits next to your rigor observation, and you have written whether it narrowed your answer or not.

In this practice scene: every joint locked and firm, no softening, which is the row "stiff and firm in every joint you test." Bracket: **6 to 30 hours.**

Does it narrow anything? No. The cooling range of 6.1 to 10.8 hours already sits entirely inside 6 to 30. Rigor did not contradict the cooling clock, and that is worth something, but it did not tighten the answer by a single minute. Write that down instead of pretending the second method helped.

The shade held around 24 °C all afternoon, which is warm. Heat speeds rigor onset and speeds its resolution. So full rigor at eight or ten hours in this warmth is unsurprising, and it would also be unsurprising at twenty. This clock is coarse here and saying so is the accurate move.

7. Sum the temperature log to an ADH total and step backwards

Start at the hour the body was found and work backwards. For each hour, subtract T_base from the hourly temperature. If the result is negative, write zero, because development stops below T_base and never runs in reverse. Keep a running total. Circle the first whole hour where the running total reaches the low end of the requirement, and the first whole hour where it reaches the high end.

You are done with this step when: the running total column is filled in and two whole-hour marks are circled, one for the low requirement and one for the high.

In this practice scene, T_base is 10 °C and the requirement is 140 to 170 ADH.

Hours back from 6:00 p.m.	Clock hour	Temp °C	Degree-hours (T − 10)	Running total
1	5 to 6 p.m.	24	14	14
2	4 to 5 p.m.	26	16	30
3	3 to 4 p.m.	27	17	47
4	2 to 3 p.m.	28	18	65
5	1 to 2 p.m.	28	18	83
6	12 to 1 p.m.	27	17	100
7	11 a.m. to 12	26	16	116
8	10 to 11 a.m.	24	14	130
9	9 to 10 a.m.	22	12	**142**
10	8 to 9 a.m.	20	10	152
11	7 to 8 a.m.	17	7	159
12	6 to 7 a.m.	15	5	164
13	5 to 6 a.m.	13	3	167
14	4 to 5 a.m.	12	2	169
15	3 to 4 a.m.	11	1	**170**
16	2 to 3 a.m.	11	1	171
17	1 to 2 a.m.	12	2	173
18	12 to 1 a.m.	13	3	176
19	11 p.m. to 12	14	4	180
20	10 to 11 p.m.	15	5	185
21	9 to 10 p.m.	17	7	192
22	8 to 9 p.m.	19	9	201
23	7 to 8 p.m.	21	11	212
24	6 to 7 p.m.	23	13	225

Going back 8 hours gives 130, which is short of the 140 the stage requires. Going back 9 hours gives 142, which clears it. So the eggs were laid **at least 9 hours** before the body was found.

Going back 14 hours gives 169, still short of 170. Going back 15 hours gives 170, which reaches it. So the eggs were laid **no more than 15 hours** before the body was found.

Raw insect window: 9 to 15 hours back, which is 3:00 a.m. to 9:00 a.m.

Now apply what you recorded in step 1. Sunrise was 6:30 a.m. Blowflies are generally not active in darkness and do not normally lay eggs at night. The stretch from 3:00 a.m. to 6:30 a.m. is dark, so it comes off the front of the window. That leaves **colonisation between 6:30 a.m. and 9:00 a.m.**, which is 9 to 11.5 hours before the body was found.

8. Overlap the three ranges and write the conclusion

Draw the three ranges as three bars on one number line, all measured in hours before the time of your reading. Read off where all of them agree. Then write the window in hours and the same window in clock times, and name every method that failed to narrow anything or that you refused to use.

You are done with this step when: one window in hours and one window in clock times are written down, and every method that was refused or that did not narrow the answer is named on your sheet.

In this practice scene:

Clock	What it gives	Window	What kind of bound it is
Body cooling	6.1 to 10.8 hours	7:10 a.m. to 11:55 a.m.	Bounds death at both ends
Rigor	6 to 30 hours	before noon, back to the previous afternoon	Bounds death loosely at both ends
Insects	colonisation 9 to 11.5 hours ago	6:30 a.m. to 9:00 a.m.	Bounds **colonisation**, not death

Read that last column carefully, because the insect row is not the same kind of statement as the other two. Eggs are laid at some point after death, never before it. So "colonisation at or before 9:00 a.m." means "death at or before 9:00 a.m." That is a floor on the interval and it is a strong one. But "colonisation no earlier than 6:30 a.m." says nothing at all about how much earlier death was. If the flies were slow to find the body, death could sit well before 6:30 a.m. and the insect evidence would look exactly the same. The insect clock puts a hard edge on one side and no edge on the other.

So the two bounds that do work are these. Death was at or before 9:00 a.m., from the insects. Death was at or after 7:10 a.m., from the cooling. Rigor contradicts neither and narrows neither.

The doubt. The point estimate from the Glaister equation was 8.0 hours, which puts death at 10:00 a.m. That 10:00 a.m. is outside the window this analysis is about to report. The first number calculated, by the simplest method, is not in the answer. That is uncomfortable and it should be, and the right move is to go check before letting it go.

Two things to check. First, could the insect requirement be wrong? The number 140 to 170 ADH came from a table for PB-1, and the species was confirmed from a preserved sample rather than guessed from a photograph. If the species had been guessed, this bound would be soft and the cooling estimate should win. It was not guessed, so the bound stands.

Second, is there a reason the cooling estimate would run short here? Yes, and it is sitting in the step 1 notes. The shade held about 24 °C, which is roughly 76 °F, for the whole span from morning to evening. That is warmer than the ordinary indoor room the 1.5 °F per hour rate was built for. A warm environment slows cooling. A body that cools more slowly than 1.5 °F per hour takes longer to lose the same 12 degrees, which means more hours actually passed than the equation reported. So 8.0 hours running low is exactly what a 76 °F environment predicts.

The two clocks were never in conflict. The conflict was between the insects and an assumption that the environment had already told us was wrong. Once the ambient temperature is on the page, they agree.

The written conclusion:

> Body found at 6:00 p.m. Rectal temperature 86.4 °F taken at 6:00 p.m. The Glaister equation gives a post-mortem interval of 6.1 to 10.8 hours, using an assumed starting temperature of 97.4 to 99.4 °F and an assumed cooling rate of 1.2 to 1.8 °F per hour. Ambient in the shade held near 24 °C, above the conditions those constants assume, so the short end of that range is the less likely end. Rigor was complete and firm in every joint tested, a bracket of 6 to 30 hours, which is consistent with the cooling estimate and does not narrow it. PB-1 eggs and first-stage larvae required 140 to 170 accumulated degree hours above 10 °C, and the site temperature log places egg-laying between 9 and 15 hours before discovery, tightened to between 6:30 a.m. and 9:00 a.m. once darkness before sunrise is excluded.
>
> I report a post-mortem interval of **9.0 to 10.8 hours**, placing death between about **7:10 a.m. and 9:00 a.m.** The early edge comes from body cooling. The late edge comes from the insect evidence, because eggs cannot be laid before death. The insect result is a minimum interval since colonisation and does not set an upper limit on the interval since death.
>
> Assumptions I could not verify: that this person's core temperature was normal at death, and that the logged shade temperature matched the temperature at the body.

Environmental factors that change the answer

"Which direction it pushes the estimate" means the direction of the error if you ignore the factor and calculate anyway.

Factor	Which method it affects	Which direction it pushes the estimate	What you must record at the scene
Ambient temperature	Cooling, ADH, rigor	Warm surroundings slow cooling, so the cooling estimate reads **too short**. Cold surroundings speed cooling, so it reads **too long**. A log that is cooler than the real temperature at the body makes the insect estimate read **too long**.	Temperature at the body, at body height, in the same light and shade, logged over the whole interval rather than once. The nearest station reading as well, so the two can be compared.

Factor	Which method it affects	Which direction it pushes the estimate	What you must record at the scene
Air movement	Cooling	Moving air strips heat much faster than still air, so the cooling estimate reads **too long**.	Wind speed, or whether a fan, vent, open window or air handler was blowing on the body, and at what setting.
Humidity	Cooling, insects	Damp skin or wet clothing loses heat by evaporation, so the cooling estimate reads **too long**. Very dry air can slow or kill eggs, which makes the insect estimate read **too short**.	Relative humidity, whether skin or clothing was damp, whether it had rained and when.
Clothing and body covering	Cooling, insects	Insulation slows cooling, so the cooling estimate reads **too short**. Covering also blocks flies, delaying colonisation, so the insect estimate reads **too short**.	Every layer and its thickness. What covered what. Whether the face, hands, and any wounds were exposed. Whether a blanket, tarp, or bag was present.
Body mass and surface area	Cooling	A large heavy body cools slowly, so the estimate reads **too short**. A small or thin body, and especially a child, cools fast, so the estimate reads **too long**.	Weight and height if available, or a written estimate with the words "estimated" next to it. Body build.
Water or wet ground	Cooling, insects	Water carries heat away far faster than air, so the cooling estimate reads **badly too long**. Flies generally cannot colonise a submerged body, so the insect clock is usually unavailable.	Water temperature. Depth. Still or moving. How much of the body was submerged or in contact with wet ground, and for how long.
Direct sun versus shade	Cooling, ADH	Sun can hold a body near ambient or warm it, so the cooling estimate reads **far too short** and can become meaningless. Sun also raises the temperature at the body above the logged air temperature, making the insect estimate read **too long**.	Sun exposure with times. What surface the body lay on and its colour. Whether shade moved across the scene during the day.
Indoor versus outdoor	All	Indoor air is steadier and often warmer than night air outside, so the cooling estimate reads **too short**. Walls, screens and closed doors delay colonisation, so the insect estimate reads **too short**.	Thermostat setting and any thermostat log. Whether heating or cooling was running. Every window and door, open or shut, screened or not.
Whether insects could reach the body at all	Insects only	Any barrier delays the first egg-laying, so the insect estimate reads **too short**, sometimes by days.	Every barrier and whether it was intact. Whether flies were present indoors. Whether anyone opened or entered the space before the scene was secured. Wrapping, containers, vehicles, burial, refrigeration.
Whether the body was moved	All	No direction can be stated. The scene's conditions are no longer the body's conditions, so every estimate may be wrong in either direction and by an unknown amount.	Lividity pattern against the position found, and whether it blanches. Drag marks. Soil or debris that does not belong. Insect species that do not belong at this location.

Factor	Which method it affects	Which direction it pushes the estimate	What you must record at the scene
Fever or hypothermia before death	Cooling, rigor	A fever raises the true starting temperature, so the cooling estimate reads **too short**. Hypothermia lowers it, so the estimate reads **too long**. Fever also speeds rigor onset.	Medical history, medications, any report of illness or of cold exposure. Write plainly on the sheet that 98.4 °F is an assumption you could not verify.
Drugs affecting metabolism	Cooling, rigor	Stimulants, some poisons, convulsions, and heavy exertion all raise body temperature before death, so the cooling estimate reads **too short**. Sedatives and alcohol with cold exposure lower it, so it reads **too long**. Exertion before death also speeds rigor onset.	What was found at the scene, prescriptions, and paraphernalia. Then hand the question to toxicology rather than guessing from the scene.

The logic a real examiner uses

You never report a single number. A single number claims a precision the measurement does not have. You report a range and you say what confidence goes with it. If the range is wide, that width is a finding about the evidence, and shrinking it to look decisive is a lie about how much you know.

You pick methods that fail differently. If you ran three methods that all depend on the surrounding temperature being what you assumed, then one wrong assumption breaks all three, in the same direction, and their agreement means nothing. Cooling is heat transfer. Rigor is muscle chemistry. Insects are a separate organism's growth. When those three agree, the agreement carries weight, because they had no shared way to go wrong together.

You write your assumptions on the same page as your answer. That the person started at 98.4 °F. That the shade log matched the body. That the species was identified rather than guessed. Anyone reading your report has to be able to see which parts of your number are measurement and which parts are assumption, and to recalculate if a later fact changes one of them.

A disagreement between two clocks is information. It is not an error to hide and it is not a reason to quietly drop the inconvenient method. Two clocks disagree when something in the environment is doing work you have not accounted for, so the disagreement points straight at the factor you missed. In the worked example, the gap between an 8.0-hour point estimate and a 9-hour insect floor is what led back to the 24 °C shade reading. The gap did the useful work. If you had thrown out the insects for being awkward, you would have reported a shorter interval and never learned why it was wrong.

Insect evidence gives time since colonisation. This is the single most misunderstood result on this card. The insect clock starts when the first female lays eggs, which is at some point after death and never before it. In warm daylight with an exposed body, blowflies can find it within minutes and lay within a few hours, so colonisation lands close to death. In darkness, in cold, in rain, indoors, inside a wrapping, inside a vehicle, or under ground, the delay can run from hours to weeks. That delay is unknown unless you have a reason to bound it. So an insect result is a minimum post-mortem interval. It tells you death happened at least this long ago. It never tells you death happened at most this long ago.

And about the case in front of you. Adult blowflies with eggs at a scene tell you colonisation had begun before the body was found. That is a real observation and it is worth recording. It becomes a number only with three more things: the species identified from a preserved specimen, the development stage measured rather than eyeballed, and an hourly temperature log for the actual location. Without a core body temperature, a rigor and lividity record, and that temperature history, there is no post-mortem interval to compute. That is why this unit keeps saying time of death is not established in the early case evidence. Do not manufacture one.

Practice problems

All scenes below are invented practice data. Unless a problem says otherwise, use a starting temperature of 97.4 to 99.4 °F and a cooling rate of 1.2 to 1.8 °F per hour for the Glaister range, and use the practice species PB-1 with T_base 10 °C.

P1. PRACTICE-TOD-A. A body is found at 4:00 p.m. in an ordinary indoor room at about 70 °F, still air, no direct sun, lightly clothed. Rectal temperature reads 89.4 °F, taken at 4:00 p.m. Give the Glaister point estimate, then give the range, then convert the range to clock times.

P2. PRACTICE-TOD-B. A body is found outdoors in continuous shade at 2:00 p.m. PB-1 second-stage larvae are present. The practice table says reaching that stage requires 180 to 240 ADH above 10 °C. Use the log below to find how long ago the eggs were laid, in hours and in clock times. Then state in one sentence what your answer does and does not say about time of death.

Hours back from 2:00 p.m.	Clock hour	Temp °C
1	1 to 2 p.m.	29
2	12 to 1 p.m.	28
3	11 a.m. to 12	27
4	10 to 11 a.m.	25
5	9 to 10 a.m.	23
6	8 to 9 a.m.	21
7	7 to 8 a.m.	19
8	6 to 7 a.m.	17
9	5 to 6 a.m.	15
10	4 to 5 a.m.	14
11	3 to 4 a.m.	13
12	2 to 3 a.m.	13
13	1 to 2 a.m.	14

Hours back from 2:00 p.m.	Clock hour	Temp °C
14	12 to 1 a.m.	15
15	11 p.m. to 12	16
16	10 to 11 p.m.	18
17	9 to 10 p.m.	20
18	8 to 9 p.m.	22
19	7 to 8 p.m.	24
20	6 to 7 p.m.	26
21	5 to 6 p.m.	28
22	4 to 5 p.m.	30
23	3 to 4 p.m.	31
24	2 to 3 p.m.	30

P3. PRACTICE-TOD-C. A body is found indoors at 11:00 p.m. Rectal temperature is 90.4 °F at 11:00 p.m. Every joint tested is stiff and firm with no softening. Give the cooling range and the rigor bracket, report the overlap in hours and in clock times, and write one sentence about what the narrowness of that overlap should make you do next.

P4. PRACTICE-TOD-D. A body is found in a bathtub at 9:00 a.m., submerged to the shoulders in standing water at about 15 °C. Rectal temperature is 88.0 °F. A student calculates (98.4 − 88.0) / 1.5 = 6.9 hours and writes "death at about 2:00 a.m." Evaluate that answer. State what you would report instead and why.

P5. PRACTICE-TOD-E. A body is found at 3:00 p.m. in a second-floor bedroom. The window is closed and latched, the screen is intact, and the bedroom door to the hallway stands open. Rectal temperature is 84.4 °F at 3:00 p.m. Room thermostat is set to 70 °F. A few adult blowflies sit on the inside windowsill and a small patch of eggs, no larvae, sits at the nose. Using the thermostat log, a specialist puts the eggs at 4 to 6 hours old. Give the cooling range in hours and clock times, state what the insect result adds, and say what the closed window does to your reasoning.

P6. PRACTICE-TOD-F. An examiner's report on an outdoor scene reads: "Death occurred between 6 and 30 hours before discovery." The file contains a rectal temperature, a note that rigor was complete, and one photograph of eggs on the body. Nothing else was recorded. List at least five things that should have been recorded at the scene. For each one, say which clock it would tighten and how.

Answers

P1.

Point estimate: (98.4 − 89.4) / 1.5 = 9.0 / 1.5 = **6.0 hours.**

Fastest cooling, lowest start: (97.4 − 89.4) / 1.8 = 8.0 / 1.8 = **4.4 hours.**

Slowest cooling, highest start: (99.4 − 89.4) / 1.2 = 10.0 / 1.2 = **8.3 hours.**

Range: 4.4 to 8.3 hours before 4:00 p.m.

Clock times: 4:00 p.m. minus 4.4 hours is 11:36 a.m. 4:00 p.m. minus 8.3 hours is 7:42 a.m. So death between about **7:40 a.m. and 11:40 a.m.**

The point estimate of 6.0 hours, which is 10:00 a.m., is the centre of that range and not the answer. Reporting 10:00 a.m. on its own discards four hours of honest uncertainty.

P2.

Subtract 10 from each hourly temperature and keep a running total, working backwards from 2:00 p.m.

Hours back	T – 10	Running total		Hours back	T – 10	Running total
1	19	19		13	4	128
2	18	37		14	5	133
3	17	54		15	6	139
4	15	69		16	8	147
5	13	82		17	10	157
6	11	93		18	12	169
7	9	102		19	14	**183**
8	7	109		20	16	199
9	5	114		21	18	217
10	4	118		22	20	237
11	3	121		23	21	**258**
12	3	124		24	20	278

Low end, 180 ADH: 18 hours back gives 169, which is short. 19 hours back gives 183, which clears it. So **at least 19 hours.**

High end, 240 ADH: 22 hours back gives 237, still short. 23 hours back gives 258, which reaches it. So **no more than 23 hours.**

Eggs were laid 19 to 23 hours before 2:00 p.m., which is between **3:00 p.m. and 7:00 p.m. the previous day.**

What it says and does not say: eggs are laid after death, so death happened at least 19 hours before the body was found, and no later than 7:00 p.m. the previous day. The 23-hour figure bounds the insects only. Death could sit well before 3:00 p.m. the previous day if anything delayed the flies from finding the body, and this result would look the same.

P3.

Cooling point estimate: (98.4 − 90.4) / 1.5 = 8.0 / 1.5 = 5.3 hours.

Fastest cooling, lowest start: (97.4 − 90.4) / 1.8 = 7.0 / 1.8 = **3.9 hours.**

Slowest cooling, highest start: (99.4 − 90.4) / 1.2 = 9.0 / 1.2 = **7.5 hours.**

Cooling range: 3.9 to 7.5 hours.

Rigor, stiff and firm in every joint with no softening: bracket **6 to 30 hours.**

Overlap: from 6.0 hours, where rigor starts, to 7.5 hours, where cooling ends. So

6.0 to 7.5 hours before 11:00 p.m., which is death between **3:30 p.m. and 5:00 p.m.**

What the narrowness should make you do: the two clocks only just touch, and an overlap that thin is a warning rather than a result. Go get the ambient temperature of that room and log it. A warm room would slow cooling and push the true interval past 7.5 hours, and heat or heavy exertion before death would speed rigor onset and pull that 6-hour edge earlier. Either finding would move one of these bars and the overlap could open up or vanish. Report the overlap and report that you consider it provisional until the room temperature is on the page.

P4.

The calculation is arithmetically correct and the answer should be refused.

The Glaister equation's 1.5 °F per hour is an average for a body in ordinary still indoor air. Water carries heat away from a body far faster than air does. So this body cooled much faster than 1.5 °F per hour, which means it reached 88.0 °F in far fewer hours than the equation reports. The 6.9-hour figure is too long, and the true interval could be a small fraction of it. The equation has no place to put the water temperature, the depth, or the movement of the water, which is another way of saying it was never built for this scene.

What to report instead: state that body cooling cannot be used at this scene with the standard constants, and say why. Record the water temperature, the depth, whether the water was still or moving, how much of the body was submerged, and how long the water had been standing. Hand those numbers to someone using a corrected cooling method built for immersion. Note also that the insect clock is probably unavailable here, because flies do not normally colonise a submerged body, so a scene like this may leave you with rigor and lividity and very little else. Writing "post-mortem interval could not be estimated by body cooling at this scene" is a complete and professional answer.

P5.

Cooling point estimate: (98.4 − 84.4) / 1.5 = 14.0 / 1.5 = 9.3 hours.

Fastest cooling, lowest start: (97.4 − 84.4) / 1.8 = 13.0 / 1.8 = **7.2 hours.**

Slowest cooling, highest start: (99.4 − 84.4) / 1.2 = 15.0 / 1.2 = **12.5 hours.**

Cooling range: 7.2 to 12.5 hours before 3:00 p.m., so death between about **2:30 a.m. and 7:50 a.m.**

What the insect result adds: the eggs are 4 to 6 hours old, so colonisation happened between 9:00 a.m. and 11:00 a.m. Death was at or before colonisation, so this sets a floor of at least 4 hours. The cooling range is already 7.2 hours at its shortest, which clears that floor easily. So the insect evidence adds almost nothing here except confirmation that the two results do not contradict each other.

What the closed window does: it explains the gap. If death was 7.2 to 12.5 hours ago and eggs were laid 4 to 6 hours ago, then somewhere between roughly 1 and 8 hours passed between death and the first egg. A latched window with an intact screen, on a second floor, is a reason for exactly that kind of delay. The flies had to get in by some other route and then find the body. So the insect number here is a weak floor, and the reasonable estimate is the cooling range.

Do not average the two numbers. They measure different things, one bounds death and one bounds colonisation, and an average of the two is a number with no meaning.

Record: whether any window, vent, or door was open at any point and when it was closed, whether the heating or cooling system was running and what the thermostat log shows, whether the screen was intact, and whether anyone entered the room before the scene was secured, since an opened door is itself a route for flies and would reset your reasoning about access.

P6.

The 6 to 30 hour range is what you get when only the weakest clock is usable. The following should have been recorded.

1. **A logged ambient temperature at the body**, taken at body height in the same shade or sun, repeated over the interval rather than once. This tightens the cooling clock, because it lets a corrected cooling model replace the fixed 1.5 °F per hour, and it also supplies the numbers the ADH sum needs.
2. **Body mass and what the body was wearing or covered by.** This tightens the cooling clock. Mass and insulation both change the cooling rate, and a corrected method needs them as inputs.
3. **Sun or shade, with the times.** This tightens both the cooling clock and the insect clock. Sun raises the body's own microclimate above the logged air temperature, which speeds larval growth and makes an uncorrected ADH sum read too long.
4. **A preserved insect sample and a live sample reared out.** This makes the insect clock usable at all. ADH constants and T_base are species-specific, and a photograph of eggs does not identify a species or measure a stage. Without the identification there is no requirement to count towards.
5. **Sunrise and sunset times, and whether it rained.** This tightens the insect clock by ruling out hours when flies would not have been laying, which is the correction that trimmed the window in this card's worked example.
6. **Whether the body was moved,** from the lividity pattern against the position found and whether it blanched under pressure. This does not tighten anything by itself, and it decides whether any of the other tightening is valid at all, because a body that was moved did not experience the temperature history of the scene it was found in.
7. **Known health information,** including fever, cold exposure, medications, and heavy exertion before death. This tightens the cooling clock by testing the assumption that the starting temperature was 98.4 °F, which is the one number in the Glaister equation that nobody at the scene can measure.

The three mistakes that cost people most

Reporting a single clock time. "Death occurred at 2:15 a.m." is the sentence everybody wants and no measurement supports. Every method on this card produces a span, and the span comes from constants that were assumed rather than measured, from an environment that was recorded imperfectly, and from a thermometer with its own error. A single time hides all of that behind a decimal point and invites everyone downstream to build on a precision that was never there. If an alibi is later checked against your one number and it fails by twenty minutes, the failure is yours, not the alibi's. Report the range. If somebody asks you to tighten it, the honest answer is what additional measurement would tighten it, which is P6.

Treating time of colonisation as time of death. The insect clock starts when a female fly lays eggs, and she has to find the body first. In warm daylight with an exposed body she may find it in minutes. Through a closed window, under a tarp, in a car boot, in the cold, in the rain, or at night, she may not find it for hours or days. That gap is invisible from the larvae. So an insect result is a minimum, and the word minimum has to stay attached to it everywhere it appears in your notes. The error runs one way and it runs in the direction that hurts. Calling colonisation "death" always makes the interval look shorter than it was, which always makes the death look more recent than it was, which is exactly the kind of wrong that puts the wrong window around the wrong person.

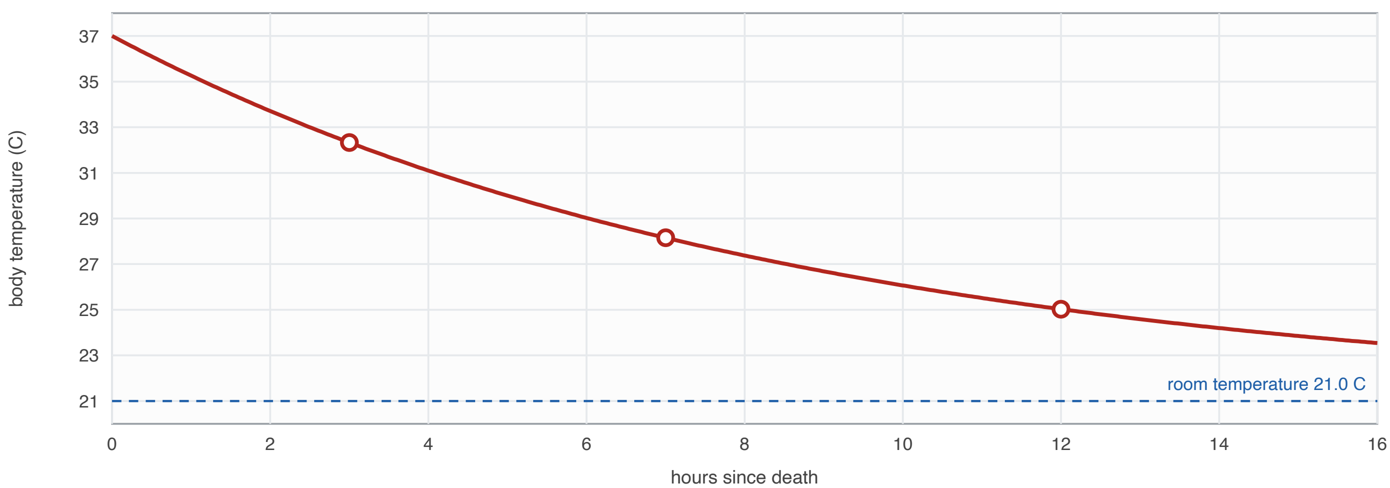
Using the Glaister equation where it does not apply. Two zones make it worst. In the first hours a body barely cools at all, so the equation reads back a small number of hours when more have passed, and it does this most strongly right where people most want a fast answer. After roughly a day the body has reached the temperature of its surroundings and the reading stops moving, so the equation saturates. Work it out for a 70 °F room and it can never report more than about 19 hours, which means it will hand you a confident 19 for a body that has been there for three days. The equation does not announce either failure. It returns a clean number both times. Knowing the two zones where it stops being valid is the only warning you get, so check the interval you are estimating against those zones before you trust the arithmetic, not after.

The lab. Estimate a post-mortem interval

These are practice records for an invented case, not the Anna Garcia case. Work all three clocks, then report the overlap.

Clock 1. Body cooling

Body cooling. Practice record.



Three readings are circled. For each one, read the temperature off the axis, convert to Fahrenheit, then run the Glaister equation. Compare your answer to the hours shown on the bottom axis.

Reading	Temp (C)	Temp (F)	Glaister PMI (h)	True hours on the axis	Difference
Reading A					
Reading B					
Reading C					

DO NOT SKIP THIS COLUMN

The last column is the point of the exercise. Glaister assumes the body loses heat at the same rate all the way down. Look at the shape of the curve and say in one sentence why that assumption fails at each end.

Clock 2. Insect evidence

A blowfly species on this scene needs about **250 accumulated degree hours** above a base of 10 degrees Celsius to reach the stage collected. Sum the log below to find how far back colonisation began.

> WHICH END IS WHICH
>
> **Hour 24 is the hour the body was found. Hour 1 is 24 hours before that.** So work BACKWARD from hour 24, adding each hour's contribution until your running total reaches 250. The hour where you cross 250 is when colonisation began, counted back from discovery.

Hourly temperature log for the 24 hours before the body was found

hour	1	2	3	4	5	6	7	8	9	10	11	12
temp C	15	17	18	18	19	20	23	23	25	23	27	26
hour	13	14	15	16	17	18	19	20	21	22	23	24
temp C	27	26	25	26	26	24	23	23	20	18	19	17

Base temperature for this species is 10 C. An hour below that contributes nothing and does not subtract.

Block	Sum of (temp minus 10) for these hours
Hours 1 to 8	
Hours 9 to 16	
Hours 17 to 24	
TOTAL	

Working backward from the most recent hour, how many hours does it take to accumulate 250? That is your colonisation estimate.

> THE TRAP IN THIS CLOCK
>
> Hours below 10 degrees contribute nothing. They do not subtract. And this gives time since **colonisation**, which is when flies first reached the body. If the body was indoors, covered, or found quickly, colonisation can be much later than death.

Clock 3. Rigor and lividity

WHAT THE RESPONDING OFFICER RECORDED AT THE PRACTICE SCENE

"Jaw and neck stiff. Arms stiff. Legs move with effort. Lividity present on the underside, and it **blanches** when I press it." Use those two observations, and nothing else, to read the table below.

What you observe	What window it suggests	Your reading
No stiffness anywhere	Under about 4 hours, **or** over about 36 hours	
Stiffness in the jaw and neck only	About 2 to 6 hours	
Stiff in the jaw, neck and arms, legs still move with effort	About 5 to 12 hours	
Stiff throughout, including the legs	About 6 to 30 hours	
Lividity blanches under pressure	Under about 8 to 12 hours	
Lividity fixed, does not blanch	Over about 8 to 12 hours	

Notice the first row. It maps to two windows at once. Say what other observation you would need to tell them apart.

Put the three together

Clock	Your range (hours before the body was found)	How much do you trust it, and why?
Body cooling		
Insects		
Rigor and lividity		
Overlap of all three		

Write the conclusion. One sentence stating a RANGE, with the assumption most likely to be wrong named explicitly.