The Pale Horse

A problem solving case study in analytical chemistry and forensic science

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A problem solving case study in analytical chemistry and forensic science

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Preface

'The Pale Horse' is one of six problem solving case studies that have been designed in order to teach analytical and applied chemistry within a 'real' life context by developing problem solving and professional skills.

Employers have long urged the Higher Education sector to produce graduates with a range of transferable skills that would make them more immediately effective in the world of work. To produce graduates who can operate in the workplace professionally, we need to go much further than just ensuring that they have a sound knowledge of chemistry, adequate practical abilities and rudimentary problem solving skills. We must ensure graduates can think critically and analytically, can interpret data and information, tackle unfamiliar open-ended problems and apply their chemical knowledge. In addition, the modern graduate must master a range of 'professional' or transferable skills including communication, team working, time management, information management, independent learning and the use of information technology.

Our approach in producing resources that address these issues in analytical chemistry has been to develop problem-solving case studies that use the contexts of forensic science, pharmaceuticals, environmental science, and industrial chemistry. These present extended problems are set in a 'real' context with incomplete or excessive data, and require independent learning, evaluation of data and information and, in some cases, do not lead to a single 'correct' answer. By tackling these cases, students are able to see the relevance of analytical chemistry and so approach the activities with enthusiasm and interest. The analytical skill developed throughout the case studies closely follow those recommended by the United Kingdom Analytical Partnership (UKAP). In addition, the transferable skills listed for each case study correlate with those identified in the RSC Undergraduate Skills Record documentation.

A Dip in the Dribble	Analytical, environmental and industrial chemistry
Launch-a-Lab	Industrial chemistry and advanced professional skills
New Drugs for Old	Pharmaceutical and analytical chemistry
Tales of the Riverbank	Analytical chemistry and environmental science
The Pale Horse	Analytical chemistry and forensic science
The Titan Project	Industrial and analytical chemistry

The case study has been extensively trialled, modified and updated. We feel that it is now in a suitable form for more widespread use. Whilst we have made every effort to ensure that this case study is free of errors and the guidelines for delivery are unambiguous, almost inevitably, we will have overlooked some detail. If users come across any errors or have any suggestions for further improvement we would be pleased to hear from you.

We thank the Royal Society of Chemistry Analytical Trust Fund for the funding of this project and the enthusiastic support of the United Kingdom Analytical Partnership (UKAP). We would like to acknowledge Tom McCreedy, Bob Knight and Tony Sinclaire (University of Hull), Bob Mackison (Chemical Solutions), Jim Miller and Helen Reid (Loughborough University), David Hardwood and Hywel Evans (University of Plymouth) for their invaluable feedback and encouragement. We also thank Catherine Brooks and Paul Taylor for assistance with staging the murder scene. Finally, we are indebted to all the friends, students and staff at various universities who have helped in the development of these case studies by their enthusiastic participation.

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Aims of the Case Study

This problem based case study sets analytical chemistry within the 'real' context of a forensic investigation of a (fictitious) suspicious death.

The case study operates by supplying information in the form of reports (see Appendix A) from various official agencies (police, pathologist and forensic laboratory) to groups of students. The students request analysis of the various types of evidence collected in order to determine the cause of death, mode of administration of poison and suggest the identity of the possible perpetrators. The requests are made at three stages during the investigation as shown in Figure 1.

The students should be able to determine that the poison used was thallium. It was administered in the gooseberry wine that was also used to make the chicken chasseur. The motives and opportunity of the various suspects are determined from the anecdotal evidence.

Who is the case study aimed at?

The case study works well with students at levels 2 and 3. It has been successfully used as part of an analytical chemistry, forensic science and professional skills module.

How long does the case study last?

The minimum contact time required is 4-5 hours and will require the students to spend approximately 12 hours in associated independent study.

How can the activities be assessed?

Students can be assessed in various ways including case summary, group or individual report, oral presentations, and individual contribution to the group effort.

What are the learning outcomes?

Students must apply appropriate knowledge of analytical techniques to tackle an extended and open-ended problem. The nature of the activities involved ensure that, in order to complete the case study, students must develop a variety of scientific (table 1) and transferable skills (table 2).

Table 1: Scientific skills

Disciplines covered	Analytical chemistry, toxicology, forensic science, forensic pathology, etc.
Scientific knowledge	Matching analytical techniques to the application. Organic analysis (e.g. identification of white powder, alcohol in blood.), inorganic analysis (determination of heavy metals by AAS) and forensic science (fingerprinting, DNA, and serology)
Handling information	Manipulation and evaluation of information and data to make realistic decisions on the evidence available.
Problem Solving	Tackling unfamiliar problems, using judgement, evaluating information, formulating hypotheses, analytical and critical thinking.

Table 2: Transferable skills

Communication skills	Oral presentations and report writing.
Improving learning and performance	Using feedback to reflect upon group and individual performance. Drawing on the experience within the group.
Information technology	Word processing reports and preparing material for presentations.
Planning and organisation	Managing an investigation, individual judgement, decision making and time management.
Working with others	Brainstorming, discussion, division of tasks and feeding back to the group.

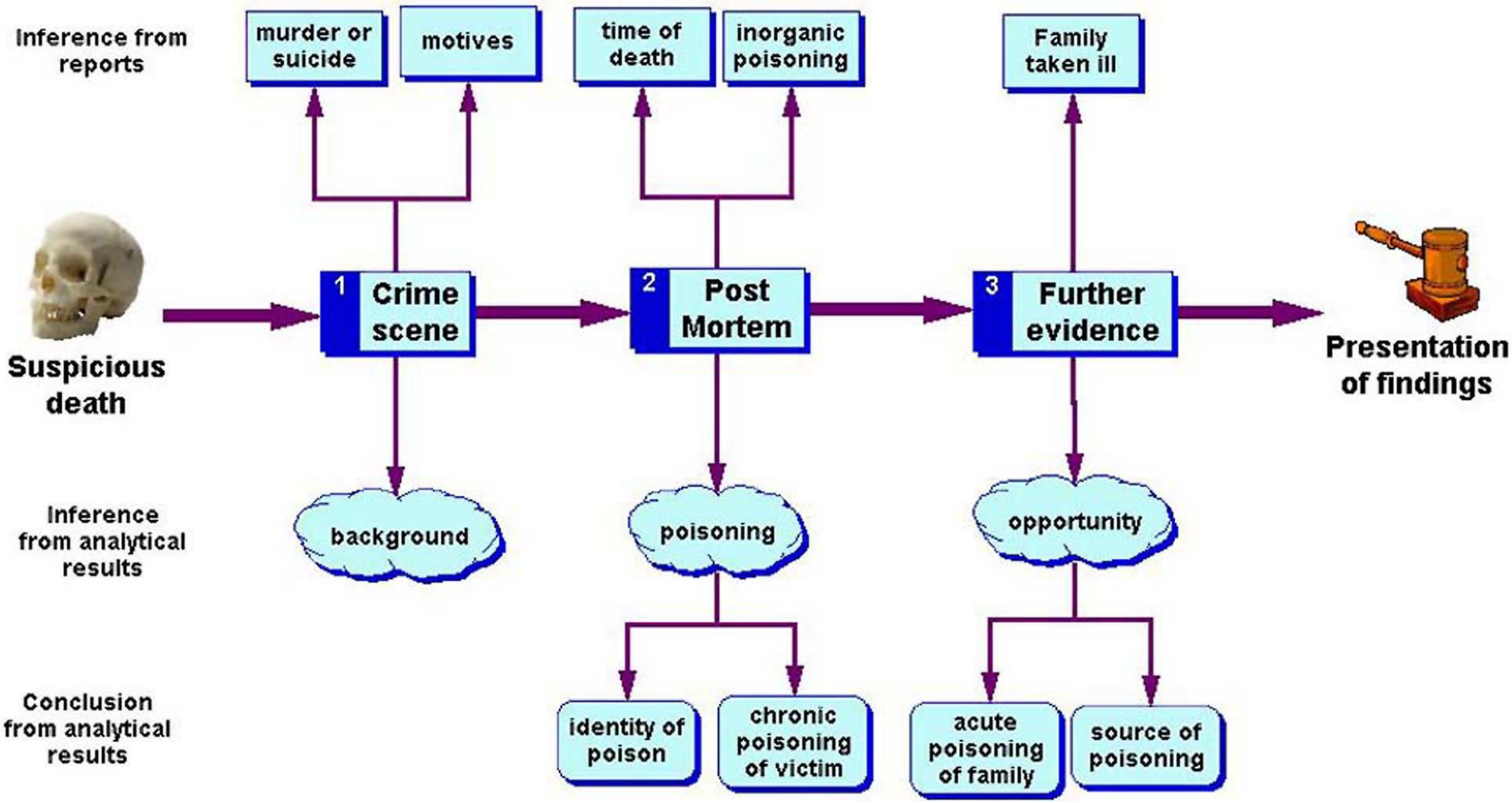

Figure 1: The case at a glance

Making it Work

The class is divided into groups of 3-6 with four being the optimum number. It is advisable to randomise the groups so that each group has a range of abilities and skills. One member should act as the chief investigating officer and is responsible for overseeing gathering of information, compiling of reports, note-taking, reporting etc.

The students should be warned that only authorised personnel can be involved in the case investigating a suspicious death and discussing a case with unauthorised personnel may jeopardise a successful prosecution. This is to dissuade them from co-operating and sharing results with other groups.

Introducing the Case

Depending upon the background of the students and the module, a preliminary introduction may be required in order to introduce the role of forensic science. A series of overheads are provided entitled the 'Place of Forensic Science' that cover the various stages of an investigation from the scene of crime to forensic laboratory and, finally, to court.

The case is introduced by explaining that each group of students is investigating the suspicious death of Maria Barberi. The tutor may also discuss the intended outcomes of the case study in terms of subject specific knowledge as well as scientific and transferable skills.

Overview of the Case

On the 10 February 2001, Brigitte Barberi found her mother, Maria Barberi, dead in her home. After an initial search of the crime scene by the scene of crimes officer (SOCO), the body was taken to the morgue. Door to door enquiries revealed that there had been a boundary dispute between the Barberis and their neighbours and that Maria's mother had just died leaving her a farm. Her husband, Martin, did not return from fishing until later that evening. A few days later both Brigitte and Martin Barberi were admitted to hospital with suspected heavy metal poisoning.

The case study operates by gradually supplying information in the form of reports from various official agencies, including the police, a pathologist and a forensic laboratory. The students request analysis on the evidence collected in order to determine the cause of death (poisoning), the identity of the poison and mode of administration.

Results from the analysis of evidence collected are available in the form of over 120 result cards covering the three possible types of collected: -

- Physical evidence, e.g. fingerprints on a wine bottle, telephone records, contents of medicine cabinet.
- Chemical evidence e.g. graphite furnace AAS for heavy metals in food, FT-IR of a white powder, identity of suspected blood stain, comparison of different wines etc.
- Toxicological evidence e.g. XRF for heavy metals in hair samples from Maria, headspace GC for alcohol in blood and ICP-MS for heavy metals in blood from Martin.)

The requests for analysis of the evidence collected are made at three stages (see Figure 1.)

The Scene of Crime

In the first one-hour session, the students are given reports from the first attending officer and investigating officer detailing the initial actions of the police officers, the police surgeon and the SOCO. After they have discussed the information, two crime scene photos are provided that show the room before and after the body was removed. Once these have been studied, the students are given transcripts of the door to door interviews with the neighbours. They are prompted to consider the types of physical evidence that they would ideally want to collect from the scene of crime.

When the students have considered this information, they are given the SOCO report that details the evidence that was actually collected. The students make a limited number of requests for analysis of this physical evidence, which may include for example, fingerprints on a wineglass, contents of a wine bottle, telephone records, identification of a white powder on a table, etc. From these results, the students should be able to determine the background of the case, and develop some theories concerning how and why Maria Barberi died.

Post Mortem

At the start of the next one-hour session, the students are given the results of their requests in the form of result cards. They are given a little time to look over these before being given the next police report. This states that Maria Barberi

was pronounced dead at the scene by the police surgeon before being taken to the morgue for the post mortem. Photographs and some background notes on the persons involved are then distributed. This normally promotes some interesting discussion among the students about the appearances of the witnesses, their background and possible motives.

Finally, the students are given the pathologist's post mortem report. From the information contained in this report, they should realise that they should be looking for heavy metal poisoning, although some students do not always realise this at this stage.

The students then request chemical analysis of the urine, blood, kidney, liver and hair samples taken at the post mortem (Appendix C). The requests are submitted to the tutor before the next session. Students normally spend about 3-6 hours in independent study in order to decide which pieces of evidence to analyse and select the most appropriate analytical technique for their chosen analyte.

Additional evidence

At the start of the third one-hour session, the students are given the results of their requests for analysis of the samples taken from the dead body. They should be able to determine whether a poison was used and, if so, what it was and when it was administered.

The students are then given the final set of reports from the investigating officer. From these reports, they are able to determine that additional evidence was collected from the scene of crime a few days later after both Martin and Brigitte were admitted to hospital with suspected acute heavy metal poisoning. The evidence collected included the chicken chasseur that Martin had been eating before he was taken ill, wine from the kitchen (see Appendix E) and blood and hair samples from the family (see Appendix D).

The students are able to make further requests for chemical analysis on this or on any previous piece of evidence. The requests are submitted before the next session. Again, the students have to spend time in independent study in order to select the appropriate analytical technique for their chosen analyte, especially if they did not receive useful results from their previous requests.

The Final Session

At the start of the fourth one-hour session, the results are returned to the students. At this stage the students should have sufficient evidence to start preparing a short presentation and a written report that consider the following.

- The state of Maria Barberi's mind at the time of death.
- Whether the death of Maria Barberi was suicide, murder, accidental death or death by misadventure.
- The cause of death.
- The identification of any poison used and how it was administered
- Whether the illnesses of Martin and Brigitte Barberi could be linked to each other and/or to the death of Maria Barberi.
- How the poison might have been obtained
- Whether further evidence is required and if a warrant could be obtained to search for this evidence
- The suspect(s) motive and opportunity.
- Whether the person the students suspect could be charged on the evidence they have gathered so far.

When students have made their presentations and/or handed in their reports in the final session, the tutor leads a review or debriefing session.

Requests for Analysis

Students make requests to the forensic laboratory on 'Evidence Request Forms' and must specify clearly the analytical technique required. By making sensible requests, students should be able to identify the cause of death, the poison used and the method of administration. The number of requests permitted is limited to encourage critical thinking and to avoid an excessive number of requests being made. This focuses the students into asking sensible questions and thinking carefully about choosing the correct analytical technique. It is made clear to the students that a rule of the case is that no useful results will be obtained if they do not specify a suitable method of analysis for the desired analyte. It is for the tutor to decide how rigorously this rule is enforced and this may depend on the desired learning objectives.

It is recommended that the cards are prepared in advance with multiple copies in envelopes arranged by evidence number. The results should be given back to the students in sealed envelopes or paper clipped together.

Submitted requests are useful in charting the changes in the student's attitude towards the case. They also indicate issues on which the tutor may wish to comment. For example, to remind students that while certain techniques are often considered to be extremely 'powerful' (e.g. NMR spectroscopy and ICP-MS), they are not necessarily always the most appropriate methods for all analytical problems.

Table 3: The analytical method code on the top left hand corner of the result cards.

Abbreviation	Method
AAS	Atomic absorption spectroscopy
DNA	DNA
FP	Fingerprints
GC	Gas chromatography headspace analysis for determination of alcohol in blood and urine.
GCMS	Gas chromatography-mass spectrometry
GF	Graphite furnace AAS for determination of heavy metals
GLC	Gas liquid chromatography
HPLC	High pressure liquid chromatography
ICP	Inductively coupled plasma-optical emission spectrometer
ICPMS	Inductively couple plasma-mass spectrometer
ID	Identification
IR	FT-IR
MS	Mass spectrometry
NMR	Nuclear magnetic resonance.
SEM XRF	Scanning electron microscope with x-ray fluorescence probe
SEM	Scanning electron microscope
TLC	Thin layer chromatography followed by FT-IR for identification.
XRF	X-ray fluorescence

When making requests, students are encouraged to consider (amongst other things) the following:

- What samples they want analysed
- What they are they looking for (specifically) from each analysis
- What analytical techniques are most appropriate
- What detection limits can be achieved by each method
- What would constitute 'normal' concentrations
- Whether the sample is likely to be a mixture of components
- If qualitative analysis is required
- If quantitative data is required
- What the meaning of a negative result might be

Results of analyses are given back to the students on prepared 'Result Cards', (see Appendix B-E). There are over 120 such cards contained in the case study including blank 'Results Cards' which are provided for any other responses that have not already been covered. This also allows the tutor to assist the students however he/she chooses, perhaps in indicating why the results from a particular chosen method of analysis would not be useful and thus, suggest another method.

The students are expected to make clear how the analytical data that they have received has informed their judgement and whether any of their conclusions are based upon the anecdotal evidence. Criminal law requires proof beyond reasonable doubt. There should still be a considerable amount of doubt at the end of the case so students should be able to make recommendations for further investigations that should be carried out by the police and the forensic science service.

Debriefing

It is recommended that at the conclusion of the case study, the tutor leads a debriefing session.

This is an opportunity to not only discuss the details of the case, but to enable students to evaluate the role of analytical science in solving this case, and help them reflect on their own development in terms of knowledge and skills.

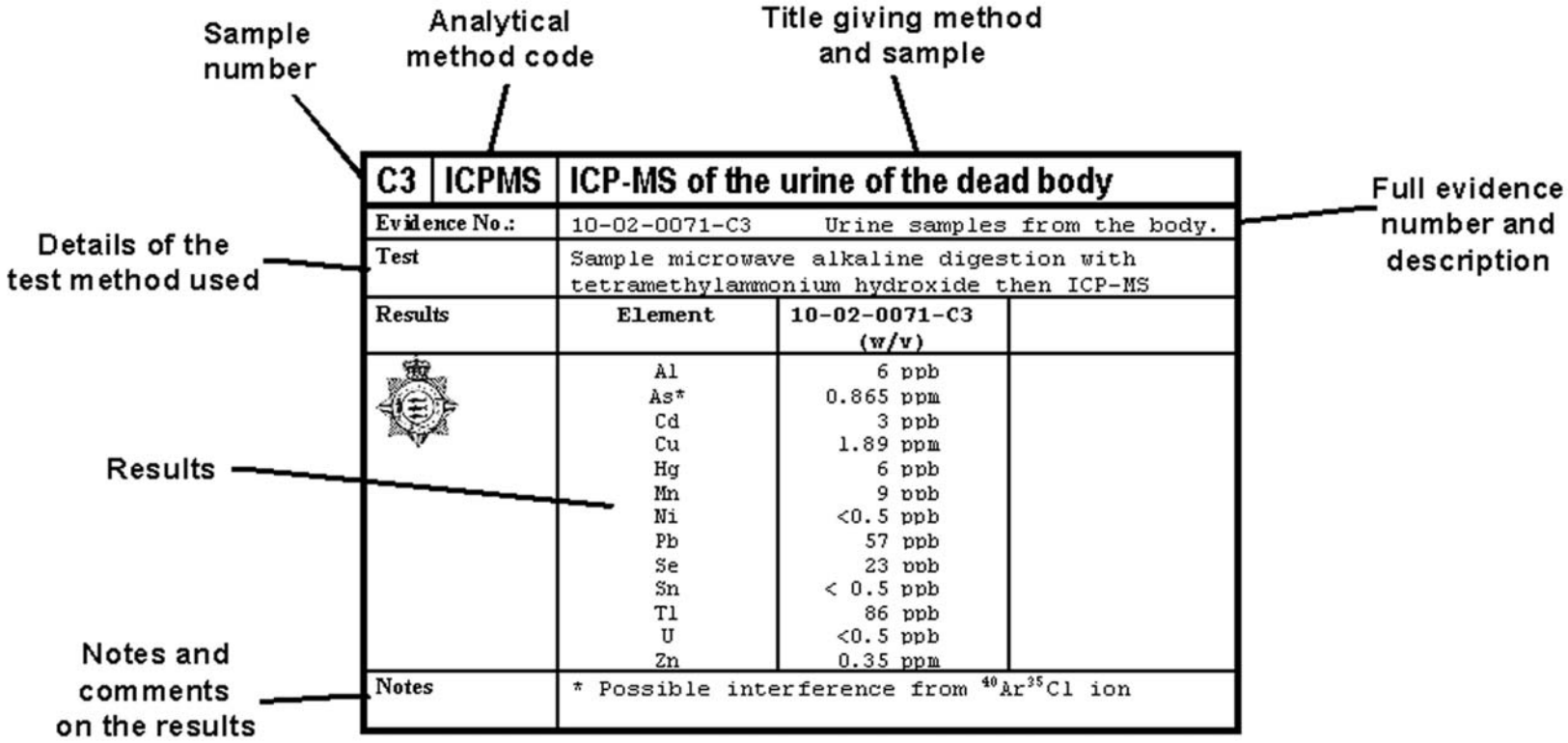

Figure 2: Example of a result card for the elemental analysis of urine from the deceased by ICP-MS.

Presentation and Assessment

Students may present their results and conclusions in several ways: -

- **Case Summary**
  These may be given in the last session to focus the students' ideas before they go onto produce reports or oral presentations (see Appendix A).

- **One page results summary**
  This may be useful for the tutor who can easily see what evidence the assumptions have been based upon without referring back to the evidence request forms.

- **Written report (group or individual)**
  This may be restricted in length and could be as short as one page incident report.

- **Oral presentation**
  The duration and content can be changed according to the demands of the tutor. Guidelines for the presentation are given in *Presentation of Case (Appendix A)*.

- **Contribution to the Group**
  This can be used to judge individual student's contribution to the activity and is particularly useful in situations when a group has failed to work well.

Table 4: Example assessment schemes

Case Summary	20%
Group summary of results	20%
Group written report	20%
Group oral Presentation	20%
Contribution to group	20%
	100%

Submitted requests	20%
Case summary	20%
Group 1 page summary of results	20%
Group oral presentation	20%
Contribution to group	20%
	100%

Case summary	20%
Group oral presentation	30%
Individual 1 page summary of results	20%
Individual report	30%
	100%

Any Questions?

1. **How flexible is the case study?**
   The case study has been used by students on analytical chemistry, forensic science and communication skills modules. The emphasis on analytical chemistry, forensic science, toxicology and key skills is up to the tutor. Example session plans are given as a guide.

2. **Is there a definitive solution to the case study?**
   No, so it encourages students to realise that in reality there is rarely one 'correct answer' The students should be able to suggest what further investigations need to be carried out in order that a prosecution could be made.

3. **What are the scenes of crime pictures for?**
   These add interest to the case and help the tutor to stress the importance of visual observation before starting any form of analysis. The tutor should ask the question 'what evidence would you want to collect?' before handing out Report 5 that lists the evidence collected by the SOCO.

4. **What are the 'witness cards' for?**
   The main characters are shown in the witness cards with some additional information. In the trials it was found that these made the case seem more realistic to the students because they gave a face to the characters.

5. **Why ask the students to identify the culprit before any analytical evidence has been gathered?**
   It is interesting for tutor and the students to reflect on the changes in their impressions throughout the case. Thus it can underline the dangers of coming to a conclusion before all the evidence is at hand.

6. **Why are there questions on the case reports?**
   It is important to get the students to reflect throughout the case. The questions encourage students to read reports carefully and to think critically about the information they are given.

7. **When is *'Typical Element Levels in Humans'* given to the students?**
   This is only given to students if specify quantitative elemental analysis on has been requested on a blood, urine, hair, kidney or liver sample.

8. **Why is the case called the Pale Horse?**
   Agatha Christie wrote a novel of the same name where the poison used was thallium sulphate.

9. **Why does Brigitte have the same surname as Martin Barberi?**
   Brigitte was adopted by Martin after he married her mother.

10. **When do you give out 'a novel way of falling out'?**
    This gives the historical toxicological background and symptoms of thallium poisoning that may be given to the students during the debriefing session.

Session Plans

These are examples of schemes of work and show the flexibility of the case study. Objectives are given for the benefit of the tutor but for obvious reasons should not be disclosed to the students.

SESSION PLAN for 2 three-hour workshops.

Objective	To think critically about the collection of physical evidence. To consider how important contamination of the crime scene and samples is to an investigation. To request analysis on the physical evidence collected.
Workshop 1 Part A	1. Overall aims of the case study are described. 2. Students are divided into groups. 3. The students are given the reports to read about every ten minutes and use the questions to discuss and prompt their investigations. • *Reports (1-2)* from first attending officer and investigating officer are given to the students and the students consider the nature and timing of the death. • *Scene of crime photos* are given to the group. • *Door to door interviews (3-4)* and consider the physical evidence they wish to collect. • *SOCO report (5)* out and the students consider what they are going to ask to be analysed.
Task 1	• Six requests for analysis are submitted on *'evidence request form 1'*
Objective	To consider if poison was used from the forensic toxicology. To determine the cause of death from the post mortem. To request chemical analysis of samples taken from the body so the poison used can be identified.
Part B	1. Students are given the results of their requests. 2. *Supplementary CID report 1 (6)* is given out. 3. *Witness cards* are given to the group 4. *Post mortem report (7)* are given out and the students consider what they want to send for toxicology.
Task 2	• Four requests for analysis in order to identify the poison used, and when it was administered are submitted on the *'evidence request form 2* (Toxicology)' before the next workshop.
Objective	To determine that thallium was used as the poison. To consider whether the illness of the other members of the family are related. To request chemical analysis to discover how the poison was administered.
Workshop 2 Part A	1. Students are given the results of their requests and should be able to identify the poison used as well as when Maria died. • The *briefing paper on typical element levels in humans* is only given to students if specific quantitative elemental analysis has been requested. 2. *Reports (8-11)* from Investigating Officer gradually given out.
Task 3	• Six requests for analysis to determine how the poison was administered. These are submitted on the *'evidence request form 3.'*
Objective	To determine whether the other members of the family were poisoned by thallium. To determine whether lethal levels of thallium were in the gooseberry wine and chicken chasseur
Part B	• Students are given the results of their requests
Task 4	• Decide which suspects had the motive and opportunity. • (OPTIONAL) The group completes the *case summary.* • Prepare oral presentation.
Objective	To present a summary of the findings of their investigation to the other groups. To appreciate the importance of analytical chemistry. To reflect upon their group and individual work. To understand that not all situations have neat solutions.
Part C	1. Students hand in of the *case summary* and / or give presentation before the debriefing. 2. The tutor leads the debriefing.

SESSION PLAN for 3 two-hour workshops.

Objective	To think critically about the collection of physical evidence. To consider how important contamination of the crime scene and samples is to an investigation. To request analysis on the physical evidence collected.
Workshop 1 Part A	1. Overall aims of the case study are described. 2. Students are divided into groups. 3. The students are given the reports to read about every ten minutes and use the questions to discuss and prompt their investigations. • *Reports (1-2)* from first attending officer and investigating officer are given to the students and the students consider the nature and timing of the death. • *Scene of crime photos* are given to the group. • *Door to door interviews (3-4)* and consider the physical evidence they wish to collect. • *SOCO report (5)* out and the students consider what they are going to ask to be analysed.
Task 1	• Six requests for analysis are submitted on *'evidence request form 1'*
Objective	To consider if poison was used from the forensic toxicology. To determine the cause of death from the post mortem. To request chemical analysis of samples taken from the body so the poison used can be identified.
Part B	1. Students are given the results of their requests. 2. *Supplementary CID report 1 (6)* is given out. 3. *Witness cards* are given to the group 4. *Post mortem report (7)* are given out and the students consider what they want to send for toxicology.
Task 2	• Four requests for analysis in order to identify the poison used and when it was administered and are submitted on the *'evidence request form 2 (toxicology)'* before the next workshop.
Objective	To determine that thallium was used as the poison. To consider whether the illness of the other members of the family are related. To request chemical analysis to discover how the poison was administered.
Workshop 2	1. Students are given the results of their requests and should be able to identify the poison used as well as when Maria died. • The *briefing paper on typical element levels in humans* is only given to students if specific quantitative elemental analysis has been requested. 2. *Reports (8-11)* from Investigating Officer gradually given out.
Task 3	• Six requests for analysis to determine how the poison was administered. These are submitted on the *'evidence request form 3.'*
Objective	To determine whether the other members of the family were poisoned by thallium. To determine whether lethal levels of thallium were in the Gooseberry wine and chicken chasseur
Workshop 3 Part A	1. Students are given the results of their requests
Task 4	• Decide which suspects had the motive and opportunity. • (OPTIONAL) The group completes the *case summary.* • Prepare a short oral presentation of their findings.
Objective	To present a summary of the findings of their investigation to the other groups. To appreciate the importance of analytical chemistry. To reflect upon their group and individual work. To understand that not all situations have neat solutions.
Part B	2. The students hand in the *case summary* 3. The oral presentation. 4. The tutor leads the debriefing.

SESSION PLAN for 5 one-hour sessions.

Objective	To think critically about the collection of physical evidence. To consider how important contamination of the crime scene and samples is to an investigation. To request analysis on the physical evidence collected.
Session 1	1. Overall aims of the case study are described. 2. Students are divided into groups. 3. The students are given the reports to read about every ten minutes and use the questions to discuss and prompt their investigations. • *Reports (1-2)* from first attending officer and investigating officer are given to the students and the students consider the nature and timing of the death. • *Scene of crime photos* are given to the group. • *Door to door interviews (3-4)* and consider the physical evidence they wish to collect. • *SOCO report (5)* out and the students consider what they are going to ask to be analysed.
Task 1	• Six requests for analysis are submitted on *'evidence request form 1'* before the next session. • (OPTIONAL) Each group is given an area of analysis to review (e.g. infrared, atomic spectroscopy, chromatography etc.).
Objective	To consider if poison was used from the forensic toxicology. To determine the cause of death from the post mortem. To request chemical analysis of samples taken from the body so the poison used can be identified.
Session 2	1. Students are given the results of their requests. 2. (OPTIONAL) Oral presentation of methods of analysis. 3. *Supplementary CID report 1 (6)* is given out. 4. *Witness cards* are given to the group. 5. *Post mortem report (7)* is given out and the students consider what they want to send for toxicology.
Task 2	• Four requests for analysis to determine the poison and when it was administered and are submitted on the *'evidence request form 2 (toxicology)'* before the next workshop.
Objective	To determine that thallium was used as the poison. To consider whether the illness of the other members of the family are related. To request chemical analysis to discover how the poison was administered.
Session 3	1. Students are given the results of their requests and should be able to identify the poison used as well as when Maria died. 2. *Reports (8-11)* from investigating officer gradually given to the students
Task 3	• Six requests for analysis to determine how the poison was administered. These are submitted on the *'evidence request form 3'* before next session.
Objective	To determine whether the other members of the family were poisoned by thallium. To determine whether lethal levels of thallium were in the Gooseberry wine and chicken chasseur
Session 4	1. Students are given the results of their requests.
Task 4	• Decide which suspects had the motive and opportunity. • (OPTIONAL) The group completes the *case summary.* • Prepare an oral presentation, one page summary of results and written report.
Objective	To present a summary of the findings of their investigation to the other groups. To appreciate the importance of analytical chemistry. To reflect upon their group and individual work. To understand that not all situations have neat solutions.
Session 5	1. Students hand in the summary of results and written report. 2. Oral presentations. 3. The tutor leads the debriefing.

SESSION PLAN for a laboratory course.

Objective	To think critically about the collection of physical evidence. To consider how important contamination of the crime scene and samples is to an investigation. To decide what analysis on the physical evidence collected will be carried out in Laboratory Session 1.
Pre-Lab 1	1. Overall aims of the case study are described. 2. Students are divided into groups. 3. The students are given the reports to read about every ten minutes and use the questions to discuss and prompt their investigations. • *Reports (1-2)* from first attending officer and investigating officer are given to the students and the students consider the nature and timing of the death. • *Scene of crime photos* are given to the group. • *Door to door interviews (3-4)* and consider the physical evidence they wish to collect. • *SOCO report (5)* out and the students consider what they are going to ask to be analysed.
Task 1	• Each group submits the outline of analysis it wishes to carry out in the lab. On consulting with the tutor they decide from the list of experiments.
Objective	To carry out the analysis on the physical evidence decided upon in Pre-Lab 1.
Laboratory Session 1	1. The samples are the white powder, the golden brown residue, the wine, residue for the medicine bottle and suspect blood sample. For example:- • Charring test to determine whether it is organic or inorganic. • Fingerprinting. • Lasagne Fusion Test • Melting point • Spot tests for drugs • TLC then FT-IR
Task 1	• Write up experiments.
Objective	To consider if poison was used from the forensic toxicology. To determine the cause of death from the post mortem. To decide what chemical analysis they are going to carry out on the samples taken from the body to determine the poison used in Laboratory Session 2.
Pre-Lab 2	1. The results are shared between the groups. 2. *Supplementary CID report 1 (6)* is given out. 3. Witness cards are given to the group. 4. *Post mortem report (7)* are given out and the students consider what they want to send for toxicology.
Task 2	• Each group submits requests for analysis it wishes to carry out in the lab to the tutor. This is discussed with tutor or the students choose from a list of experiments.
Objective	To carry out the analysis on the physical evidence decided upon in Pre-Lab 2.
Laboratory Session 2	1. Different groups perform one of the following and the results are pooled. • Determination of alcohol in blood by GC • ICP-MS or ICP-OES of biological samples that have been pre-digested. • Toxicological screen of biological samples by GLC-FID • Toxicological screen of biological samples by HPLC-diode array
Task 3	• The results are written up and given to the other groups before the next laboratory session.

Objective	To determine whether thallium was used as the poison. To consider whether the illness of the other members of the family are related. To request chemical analysis to discover how the poison was administered.
Pre-Lab 3	1. The results shared between the groups. 2. *Reports (8-11)* from Investigating Officer gradually given to the students
Task 3	• Each group submits request for analysis it wishes to carry out in the lab. This is discussed with tutor or the students choose from a list of experiments.
Objective	To determine whether the members of the family were poisoned by thallium. OR: To determine that lethal levels of thallium were in the Gooseberry wine and chicken chasseur
Laboratory Session 3	1. Different groups perform one of the following and the results are pooled. • FAAS of food and drink samples looking for Tl • GF-AAS of food and drink samples looking for Tl • ICP-MS or ICP-OES of food and drink samples. • SEM XRF of hair samples. • XRF of hair samples.
Task 4	• The results are written up and given to the other groups before the Post-Lab Session. From this the groups decide which suspects had the motive and opportunity then to complete the *case summary*. • Prepare a short oral presentation of their findings.
Objective	To present a summary of the findings of their investigation to the other groups. To appreciate the importance of analytical chemistry. To reflect upon their group and individual work. To understand that not all situations have neat solutions.
Post-Lab	1. Students hand in of the *case summary.* 2. Oral presentations. 3. The tutor leads the debriefing.

The Pale Horse Explained

Mrs Maria Barberi (aged 39) of 25 Thurmaston Road, Beauport, Midshire was found dead by her daughter (Brigitte) at 16:05 on the 10/2/01. Her daughter was the last person to see her alive at 08:00. The last telephone call that was made from the premises was at 11:23, excluding Brigitte calling 999. There was no evidence of a struggle or forced entry. Her husband (Mr Martin Barberi) did not return from fishing on the River Coley until 18:46. Miss Brigitte Barberi was sent to stay with her grandparents (Mr and Mrs A.F. Barberi.)

The first attending officer was PC Chris Rose who then conducted door to door interviews of the neighbours. The Investigating Officer from CID was Detective Sergeant Mark Holme. The Police Surgeon (Dr. Steven Middleton) was summoned and he pronounced death at 17:00. After the initial search of the crime scene by SOCO Annie Barnard, the body was taken to the morgue of Beauport General Hospital.

Mr Peter Crippin M.D, who performed the post mortem, stated the body showed evidence of inorganic poisoning. The hair loss and symptoms described seem to indicate chronic thallium poisoning. Samples were sent for toxicology to Midshire Forensic Laboratories and the analyses were performed Dr. Simon Gough.

Toxicology screen for heavy metals by ICP found toxic levels of thallium in the blood, urine, kidney, liver and hair. Thallium was found in the stomach contents so Maria may have ingested thallium with the last thing she ate or drank. The levels of thallium determined by SEM-XRF in the hair showed that she had been exposed for about a month. Cirrhosis combined with the blood alcohol levels indicated that she might have had an alcohol problem (GC headspace vapour analysis.) The drug toxicology screen by HPLC and GLC showed presence of citalopram (Cipramil), a seratonin re-absorption inhibitor, to treat depression.

On the night of 12th February, Martin Barberi was admitted to hospital. Two days later his stepdaughter, Brigitte was also admitted to hospital. Toxicology showed that both had been recently exposed to thallium because no thallium was found in their hair. They were suffering from acute thallium poisoning.

The last meal that all of the Barberi family ate was the chicken chasseur cooked by Maria. The highest levels of thallium were in the white sauce of the chicken chasseur. Thallium was also found in the gooseberry wine. The white sauce was probably made from the gooseberry wine. This wine was one of the bottles that Tim Dollar gave Martin Barberi 'a few weeks before.'

Time of Death

The head wound did not contribute to Maria's death and was caused by her striking the porcelain elephant when she collapsed whilst calling for assistance on the telephone. Maria was probably dead or in a coma before she struck this as there was very little bleeding.

Death occurred between 13:00 and 15:00 hours according to the post mortem She was last seen alive at 8:00 by her daughter. Interestingly, *The Pale Horse* by Agatha Christie was found on the table in the living room. The contents of the cupboard under the sink did not contribute to the death.

The Poison

Thallium sulphate is a colourless, tasteless salt that dissolves readily in water. About 800 mg is a fatal dose for an adult. It takes about a week to start working, and the symptoms are often confused with diseases such as encephalitis, epilepsy and neuritis. It mimics the essential element potassium in potassium-activated enzymes in the brain, muscles and skin.

Acute thallium poisoning produces nausea, vomiting, diarrhoea, pain in the extremities, weakness, coma, convulsions and death. Chronic thallium poisoning causes weakness, pain to the extremities and loss of hair. Its use as a pesticide is prohibited in most Western countries.

The post mortem indicated inorganic poisoning. Heavy metal poisons include antimony, arsenic, cadmium, lead, mercury and thallium. The symptoms especially the hair loss from Maria Barberi indicate that it was probably thallium poisoning.

Maria Barberi showed classic chronic thallium poisoning. SEM-XRF of her hair showed exposure to thallium for about a month. This is supported by GP records and the statement from Mr Barberi stating when she came to see him about her allopecia etc. It is probable other bottles were poisoned that Maria consumed alone. She was an alcoholic and on antidepressants.

For Martin Barberi acute thallium poisoning came from the chicken chasseur consumed on the 9th and 12th, also possibly drinking some of the gooseberry wine. He was not suffering from alcohol poisoning (40 mg per 100 ml of blood). Toxic levels were found in his blood but normal levels of thallium found in the hair so had been exposed for less than a week.

Brigitte only ate the chicken chasseur. Her thallium poisoning was severe because of her low body weight. Selenium in her hair was from the anti-dandruff shampoo

Possible Motives.

Martin Barberi, a public health inspector, was married to Maria. Were the deaths of her father and mother suspicious? Did he marry her for the inheritance of the farm? What were the reported arguments about?

Tim Dollar, a builder, has a police record for GBH. Last year there was an acrimonious dispute over the boundary and the barking of the dog. PC Rose cautioned him (Report 3).

Helen Dollar is a secretary. Could have acted alone or in concert with her husband?

The senior farm hand could loose his job if Maria Barberi sells the farm. Was the accident to her father suspicious? Was the sudden death of her mother suspicious?

Simon Shaw (ex-husband) had been violent towards Maria (Report 3-4) and probably caused the skull fractures (post-mortem). The phone-call to him on the 8th and 9th February was over the case coming up (Report 4) regarding visiting rights to Brigitte, his daughter.

It could have been suicide due to depression probably caused by the death of her mother and the stress over the inheritance, the reported arguments and pending court case. In addition, she probably had a drink problem because of the cirrhoses of her liver and the blood alcohol at death was 160 mg per 100 ml of blood. This is twice the legal driving limit and she would have committed an offence if she had picked up her daughter from school. Only 15-25 mg per hour is metabolised. Note that bacteria can also produce alcohol after death.

Opportunity

Brigitte, Maria and Martin Barberi had the opportunity to put the poison in the gooseberry wine at 25 Thurmaston Road. The wine did not have a seal and the amount of thallium required was less than a quarter of a teaspoon.

Tim Dollar made the wine so he and his wife both had opportunity to put the poison in the wine. Only Maria Barberi and Tim Dollar's fingerprints were found on the bottle.

The opportunity of the other suspects is uncertain. This would probably require more enquiries. Mr. Simon Shaw has not been interviewed yet.

Access to the Poison

Below assumes obtaining the thallium by direct means without any subterfuge.

- Martin Barberi is a Public Health Inspector so it is likely that he would have access to an old supply of thallium sulphate in the form of rat poison.
- Tim Dollar is a builder. He could have obtained it through a house clearance.
- Helen Dollar is a secretary at Titan Industries plc who are pigment manufacturers.
- Unknown access to thallium by the other suspects.

Unlikely Suspects

It is unlikely that the guilty person is outside those above but more investigation is required.

- Brigitte has been discounted for lack of motive.
- Mrs. Kathy Stevens has been eliminated for lack of motive and opportunity.
- Senior Farm Hand has been discounted for lack of opportunity but has not been interviewed yet.

The Next Course of Action

- Request a search warrant for the Dollar's house.
- Search 25 Thurmaston Road for thallium containing compounds, i.e. rat poison.
- Interview Simon Shaw (the ex-husband.)
- Ask permission or request a search warrant for Tidstall Farm.
- If poison were found then this could be traced back to the person who purchased it or obtained it.

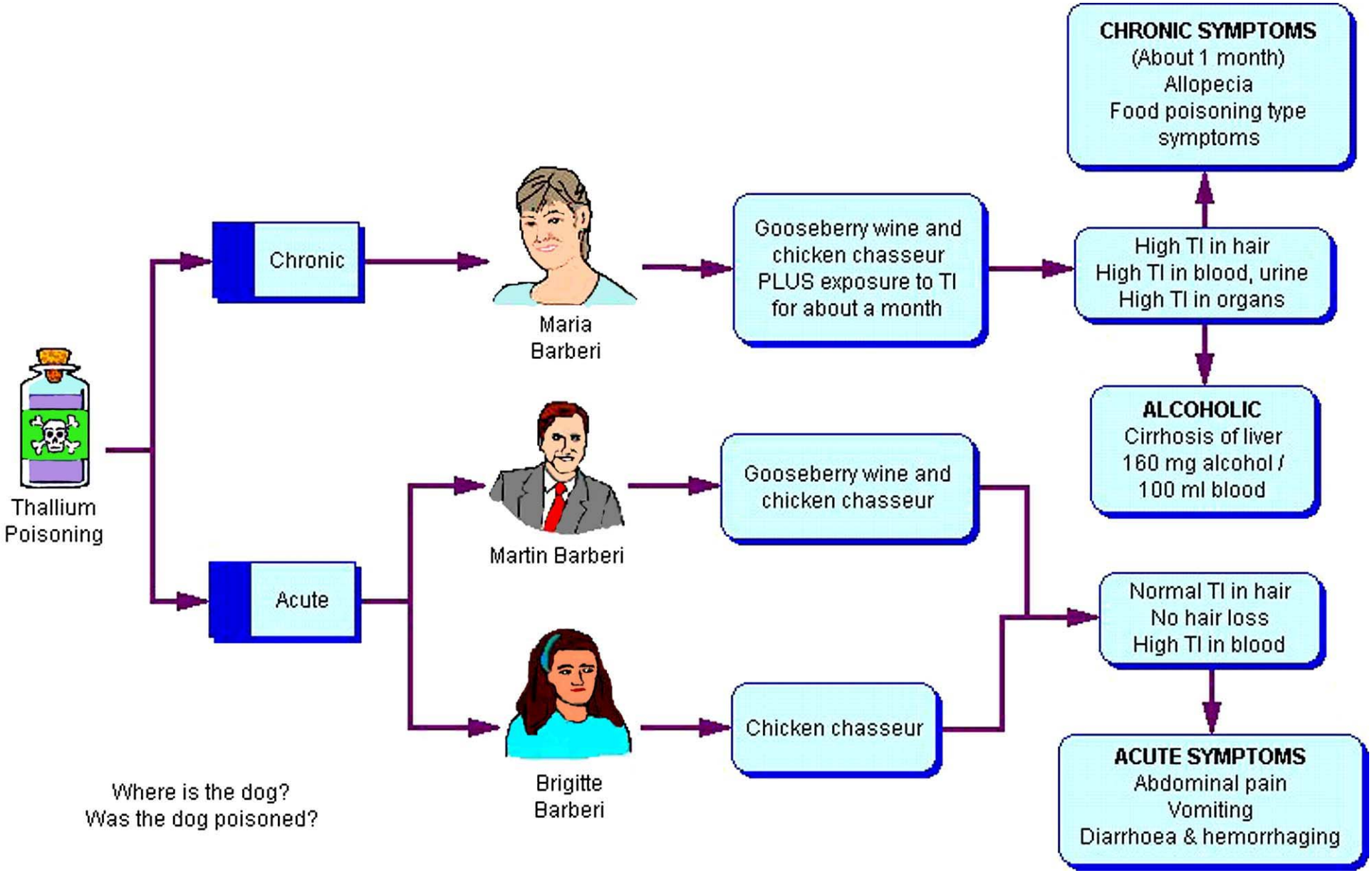

Figure 3: The Pale Horse explained.

Table 5: Inorganic analysis results expressed in ppb for the evidence collected. (Note different methods may give different results.)

	Sample	Al	As	Cd	Cu	Hg	Mn	Ni	Pb	Se	Sn	Tl	U	V	Zn	
	Blank	ND	1	2	7	29	32	ND	3	4	483	0.3	0.2	6	27	No Tl
B1	wine glass	ND	20	4	51	39	1060	ND	60	6	446	0.5	0.1	20	1170	No Tl
B2	Chateau de Graville	ND	20	4	51	41	1010	ND	65	6	421	0.6	0.1	20	1120	No Tl
B4	white powder	ND	25	5	91	21	101	ND	6	11	430	0.3	<0.1	63	34	No heavy metal contamination.
B5	medicine bottle	ND	22	<2	91	21	136	ND	5	21	425	<0.1	<0.1	73	580	Bo Tl
C1	blood from dead body	5	90	2	1090	2	10	<0.5	21	10	<0.5	70	<0.5	ND	7200	Blood sample showed high levels of thallium.
C2	urine from dead body	<5	65	98	25000	2200	1500	220	18900	990	<0.5	1200	<0.5	ND	1020	High Tl root and within four cm of it. So exposure to poison started about a month before.
C3	hair from dead body	6	80	3	1890	6	9	<0.5	57	23	<0.5	86	<0.5	ND	350	Blood sample showed high levels of thallium.
C4	kidney from dead body	400	<0.5	28000	3700	290	45000	190	860	810	ND	490	0.7	ND	18900	Kidney showed high levels of thallium
C5	liver from dead body	0.5	<5	1500	800	65	2200	40	480	250	ND	290	<0.5	ND	35600	Liver showed high levels of thallium
C6	stomach contents from dead body	<5	70	10	150	70	560	ND	1200	810	ND	8	<5	ND	15900	Tl levels in stomach contents showed that it had been consumed some 6 hours before.
S1	Martin's blood	ND	<1	2	1100	3	11	<5	200	9	ND	200	<0.5	ND	ND	40 xs normal Tl levels
S2	Martin's hair	ND	100	1500	18000	1800	2500	500	43500	1200	ND	4	<0.5	ND	ND	So Tl exposure in the last couple of days.
S3	Brigitte's blood	ND	<0.5	3	1900	6	9	<5	57	23	ND	180	<0.5	ND	ND	36 xs normal Tl levels
S4	Brigitte's hair	ND	200	300	10200	1100	1300	100	10200	21400	ND	<0.5	<0.5	ND	ND	Exposed to Tl in last couple of days. High Se due to dandruff shampoos.
H1	Red wine	ND	14	2	64	20	935	ND	52	1	391	0.3	0.3	41	585	No Tl
H2	White wine	ND	11	3	45	37	1370	ND	21	4	360	0.2	<0.5	13	1020	No Tl
H3	Gooseberry wine	ND	25	3	91	21	2340	ND	35	11	430	16100	0.2	63	1420	Toxic amount of thallium was found.
H4	Beer	ND	0.9	2	14	21	55	ND	4	4	495	0.2	0.4	33	37	No Tl
H5a	Potato	ND	<5	5	91	41	19	ND	2100	11	480	600	2	8	34	Highest level of Tl in white wine sauce of the chicken chasseur.
H5b	White sauce	ND	<5	3	0.4	72	11.4	ND	41	50	440	26700	0.4	70	7200	
H5c	Chicken	ND	10	21	100	65	1200	ND	1900	180	410	3400	3	90	800	

Table 6: Comments on results of organic analysis on the evidence collected.

	Sample	Notes
B1	wine glass	The glass contained wine from the Chateau de la Graville 1999. Comparing TLC then FT-IR (organics), HPLC, GLC and ICP-MS (trace metals.) Prints from Mr and Mrs Barberi were on glass.
B2	Chateau de Graville, 1999	Prints from Mr Barberi and an unknown male found. The latter was identified as belonging to Mr Tim Dollar. No organic impurities.
B3	CO detector	CO detector showed that carbon monoxide poisoning could be discounted. In addition, the body did not show the pinkness associated with this form of poisoning. Only smudged fingerprints were found.
B4	white powder	The white powder was fructose (determined by FT-IR and HPLC) and probably used in the preparation of jam. It had no heavy metal contamination.
B5	medicine bottle	The medicine on the mantle place was Cocodamol as prescribed to Mr Barberi and was not contaminated.
B7	suspected blood sample	Not blood (luminol test negative.) The suspected blood sample was burgundy red paint left over from the painting of the hall. The paint tin and brush was left in the front room.
B8	drug cabinet	The contents of the drug cabinet did not yield any illegal drugs.
B9	red stain on wall	The red stain on the wall was paint.
C1	blood from dead body	160 mg of ethanol per 100 ml of blood (twice the legal driving limit). No illicit drugs found. The prescription anti-depressant citalopram (Cipramil) was found.
C2	urine from dead body	The prescription anti-depressant citalopram (Cipramil) was found.
C3	hair from dead body	
C4	kidney from dead body	No organic poisons found (GC-MS or HPLC-MS).
C5	liver from dead body	No organic poisons found (GC-MS or HPLC-MS).
C6	stomach contents from dead body	No organic poisons found (GC-MS or HPLC-MS).
S1	Martin's blood	40 mg of ethanol per 100 ml of blood (about half the legal limit to drive)
S2	Martin's hair	
S3	Brigitte's blood	
S4	Brigitte's hair	
H1	Red wine	No organic impurities.
H2	White wine	No organic impurities.
H3	Gooseberry wine	No organic impurities. Mr Tim Dollar made the gooseberry wine. The fingerprints of Mrs Barberi and Mr Tim Dollar were identified.
H4	Beer	No organic impurities.
H5	Part eaten meal	

Who is Who?

The main characters are shown on the *WITNESS CARDS*. Tables 7-9 shows all the characters involved in the case.

Table 7: Relatives of Mrs Maria Barberi.

Relations	Age	Occupation	Notes
Mrs Maria Barberi	39	A&E Nurse at Beauport General Hospital	Dead body. She was taking Cipramil (citalopram) for depression caused by her parents' deaths. Evidence that she been drinking heavily from post mortem.
Mr Martin Barberi	30	Public Health Inspector for Midshire County Council	Second husband and step father to Brigitte (Shaw) Barberi. A keen angler.
Brigitte Barberi	13	Schoolgirl	Daughter of Maria who found the body of her mother. She is the daughter of Mr Simon Shaw.
Mr and Mrs A.F. Barberi	60s	Retired	Mr. Barberi's parents (phone records.) On the night of 10/2/01, Brigitte stayed with them (Report 6)
Mr Simon Shaw	38	Seaman (Ex Royal Navy)	Maria's ex-husband and father of Brigitte. Divorced due to wife battering. (Report 3 & 4: Phone records)
Mrs Betty Moore (Maria's mother)	died 12/00	Owned Tidstall Farm before her sudden death.	Mother to Maria who died a month or two before. The farm was left to her only daughter Maria. (Report 4)
Mr Moore	died 10/98	Farmer at Tidstall Farm	Maria's father who died two years previously of an accident on the farm. (Report 4)

Table 8: Neighbours and friends.

Neighbours and other characters	Age	Occupation	Notes
Mr. Tim Dollar	42	Self employed builder	Next door neighbour at 27 Thurmaston Road. Had a boundary dispute over the placing of a fence and complained of the dog barking. Gave the Barberi's some bottles of Wine. (Report 3-4)
Mrs Helen Dollar	28	Secretary at Titan Industries PLC (pigment manufacturer)	Wife of Tim Dollar. (Report 3-4)
Mrs. Kathy Stevens	70	Retired Science Teacher	Widow and next door neighbour at 23 Thurmaston Road (Report 4)
Senior Farmhand	50+	Runs the Tidstall Farm	Runs the farm, after the death of Maria's father and mother (Report 4.)
Mrs. H. Petifer	30s	Unknown	Maria telephoned her on the morning of her death. Probably a friend of Maria's. (Phone records)

Table 9: The investigation team.

Investigating Team	Occupation	Notes
Chris Rose	Police Constable, Beauport Police Station, Midshire Police	First police officer on the scene and performed the door to door interviews (Report 1, 3 and 4).
Annie Barnard	Scene of Crime Officer, Midshire Police	Performed the scene of crime search as described in Reports 5.
Mark Holme	Detective Sergeant in CID	Investigating Officer (Report 2, 6, 9-11)
Mr. Peter Crippin, M.D.,	Pathologist at Beauport General Hospital.	Performed the post mortem on Maria Barberi (Report 8)
Dr Steven Middleton M.D.,	Police Surgeon (Forensic Medical Officer)	Pronounced death of Maria Barberi (Report 3)
Simon Gough, BSc, MSc., PhD	Forensic Scientist at Midshire Forensic Laboratory	Performed the forensic analysis on the samples (Report 8 & 12).

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