



## ICE - Geometric Series

*The use of morphine as an analgesic for the relief of postoperative pain is quite a recent development, although the recreational use of opiates (the family of drugs that morphine belongs to) has been traced back more than 5000 years<sup>1</sup>.*



Figure 1: Recognition guide for Roxanol™ from the Physicians' Desk Reference, 1999.

*In 1834 the Scottish physician Dr. Alexander Wood perfected the technique of administering morphine via intravenous injection using a syringe. This method is still in common use today.*

*According to the Forensic Toxicology Drug Information Fact Sheet (2000) distributed by the Toxicology and Accident Research Laboratory of the Federal Aviation Administration, the half-life of morphine in the body is approximately four hours. Morphine obeys the "linear law of pharmacokinetics" - that is, the amount of morphine remaining in the body is given by an exponential decay function.*

- *Why do you think that medical personnel would be interested in knowing about how much Roxanol®<sup>2</sup> is in the patient's bloodstream at any particular time?*

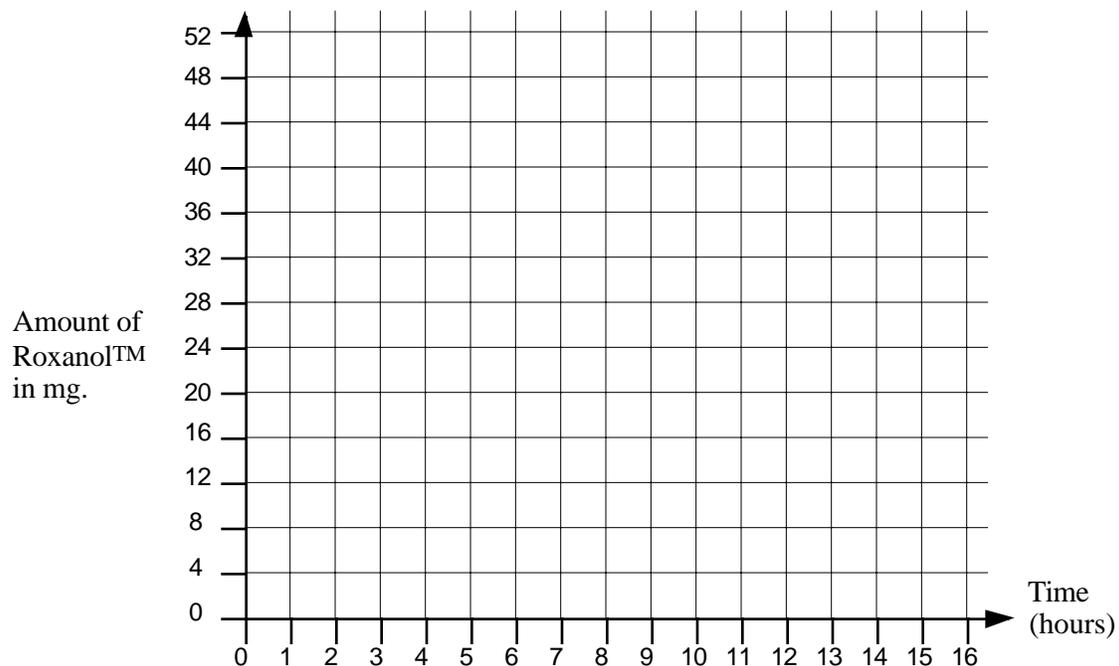
<sup>1</sup> Archaeological evidence suggests that the members of the Sumerian civilization deliberately cultivated opium poppies in southern Mesopotamia at around 3400 BCE (Source: [www.pbs.org](http://www.pbs.org))

<sup>2</sup> Roxanol® is a registered trademark of Roxane Laboratories, Inc.

• According to the manufacturer's recommendations, a patient should be injected<sup>3</sup> with 1 ml of Roxanol® immediately after an operation. Find a formula for amount of Roxanol® in the patient's blood stream as a function of time.

• How much Roxanol® remains in the patient's blood stream four hours after receiving the first injection?

• The manufacturers of Roxanol® recommend that this dose is repeated every four hours. Sketch a graph showing how the amount of Roxanol® in the patient's bloodstream changes with time.



<sup>3</sup> According to the Roxanol® Dosage and Administration Fact Sheet, 1999, the recommended dose is 10 to 30 mg every four hours, depending on the patient's response to the drug. Source: Roxane Laboratories, Inc.

- Use your graph (along with any other ways that you are able to understand the problem) to complete the table given below.

|   |   |   |    |    |    |
|---|---|---|----|----|----|
| Time (hours)                              | 0 | 4 | 16 | 20 | 32 |
| Amount of Roxanol® in Patient's Body (mg) |   |   |    |    |    |

- Let  $N$  denote the number of injections of Roxanol® that the patient has received. Find an equation for the amount of Roxanol® (in mg) that the patient has in his or her body immediately after receiving the  $N^{\text{th}}$  injection.

- The minimum lethal concentration<sup>4</sup> of morphine in the blood is between 5mg/100ml and 40 mg/100ml. How long does it take before the levels of morphine in the patient's blood could reach dangerous levels? (Assume that the patient has 4700 ml of blood<sup>5</sup>.)

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<sup>4</sup> Forensic Toxicology Drug Information Sheet (2000). Distributed by the Toxicology and Accident Research Laboratory, Federal Aviation Administration, Office of Aviation Medicine.

<sup>5</sup> Source: World Book Encyclopedia (1998 Edition).