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Name: ___________________________________

Introduction / Homeostasis

Objectives:

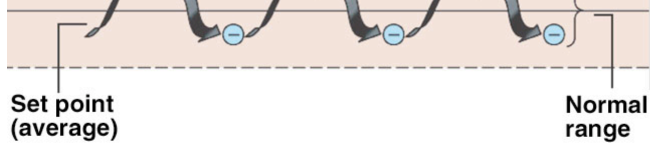
1. Define the term homeostasis.
2. Explain how the negative feedback control of effectors helps to maintain homeostasis.
3. Explain why the internal environment is in a state of dynamic, rather than static, constancy.
4. Statistics : Understand the meaning and use of basic statistics in interpretation and analysis of data and in the establishment of "Normal Values" or ranges.
5. Demonstrate ability to calculate a mean (average) & standard deviation for a data set.
6. Demonstrate the ability to determine whether two sets of data are statistically different.

Introduction: Homeostasis

Human physiology is the study and examination of the physical and chemical factors responsible for the vital life processes of the human body. The cell is the basic structural and functional unit of the body, forming its tissues, organs, and organ systems. Each cell comprising the body is specifically adapted to perform specialized functions *under particular environmental conditions*. Although the body is comprised of greater than 100 trillion specific cells, each with its own specific optimum conditions, the body as a whole functions optimally under a specific set range of conditions. The body and essentially all of its cells therefore function to defend and maintain this relatively constant environment. The term *homeostasis* (coined by Water Cannon - 1932) is used by physiologists to describe the maintenance of this *dynamic constancy*. Homeostasis is our body's vital tightrope act resulting in the maintenance of all internal variables relatively stable. In fact nearly all body systems function to collectively maintain this dynamic constancy.

Homeostasis is a key unifying concept in all aspects of human physiology. The concept essentially allows complex regulatory processes to be understood in terms of "how" and "why". Since the body strives to maintain a dynamic consistency, any deviation can result in non-optimum performance of tissues, organs, organ systems and eventually the organism. This non-optimum performance of body structures characterizes *disease*. Therefore inability of the body to maintain any of the many internal variables results in disease. In a healthy individual, deviations from the dynamic consistency are usually overcome through appropriate autonomic adjustments in the physiological systems. For example, cardiac & respiratory rates are increased in exercise in response to increasing levels of blood CO_2 and blood acidity. Following the completion of an exercise, the body must readjust the cardiac & respiratory rates to reflect the decrease in metabolic demands. If this readjustment is not accomplished, the elevated breathing rates can lead to respiratory alkalosis (increased pH), loss of consciousness, and possible permanent nerve damage. The failure the body to maintain homeostasis, resulting in disease, can occur for a variety of reasons. Some of these include, infection (bacterial, viral), genetic disposition, immune disorders, trauma, aging, nutritional factors, etc. Therefore the health of an individual is contingent upon his/ her ability to sense deviations from normal and make necessary adjustments to re-establish the dynamic consistency.

Fig. 1: Negative Feedback Loops



One of the primary prerequisites for being a healthy individual is the ability to maintain homeostasis. When homeostasis is disturbed a <u>sensor</u> (sensory neuron) detects the deviation from the optimum running value or <u>set point</u>. The sensor then sends this information to an <u>integration site</u> (CNS) for the disturbance to be evaluated. Once evaluated an <u>effector</u> (muscle or gland) is activated. The effector will initiate changes which *oppose* those that initially activated the sensor. These compensating, opposing changes are called <u>negative feed back responses (loops)</u>. (Fig. 2)

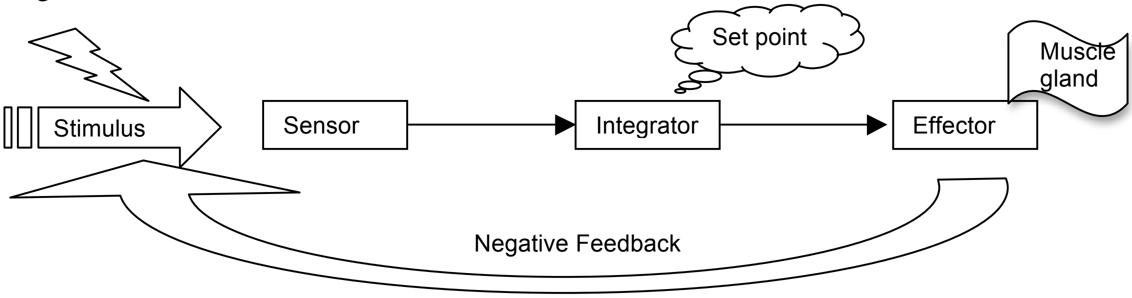
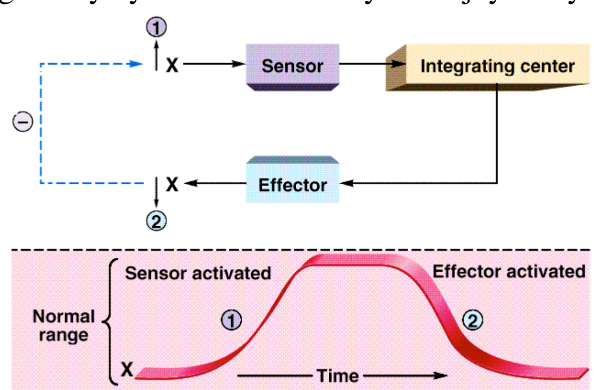


Fig. 2: Negative Feedback Responses

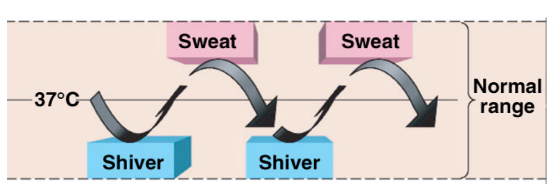
Negative feedback responses can be easily demonstrated using thermoregulation as an example. As body temperature increases in response to exercise (or some other parameter) – a thermoreceptor (<u>sensor)</u> detects this deviation. The sensor then sends this information to the hypothalamus (<u>integration site</u> - CNS) for the disturbance to be evaluated. Once evaluated <u>effectors</u> are activated. If significant temperature increases are sensed, sweat glands will be activated. The sweat glands (effectors) initiate changes *opposing* those which initially activated the sensor. In this case, sweating will function to cool the body bringing the body temperature back to its optimum running level or set point of 98.6°F. Reestablishing the set point thus completes the negative feedback response (Fig. 3). Just like a house's heating system, our bodies defend their set point temperature by utilizing the neural thermostat in the hypothalamus and our temperature effectors of sweating and shivering. The compensatory initiation of sweating or shivering results in the thermoregulatory dynamic consistency we enjoy everyday (fig. 4).

Fig. 3: Negative Feedback



When compensatory mechanisms on either side of a set point are working together (ie increasing and decreasing body temperature), only slight deviations from a set point result. These ongoing compensatory changes result in a state of *dynamic constancy* referred to as the *<u>normal range</u>* (fig. 3). Homeostasis is therefore a *state of dynamic*, rather than absolute, *constancy*. Any deviation without compensation will result in reduced body function as optimum running conditions are not maintained.

Fig. 4: Dynamic Consistency



Generally physiological regulatory processes are far more complex than a single sensor and effector. While most are sensed and controlled by more than one set of sensors and effectors, there are exceptions. The most notable exceptions are referred to as *Positive Feedback Responses*. Positive feedback responses function to exacerbate change initiated rather than compensating for it. Responses gain in momentum as the results of the pervious events encourage even stronger changes. As in the case of blood clotting, once the response is initiated it continues and progressively gains momentum. The effectors are clotting proteins which function to stimulate more clotting proteins, eventually culminating in a thick blood clot, at which point the response is stopped. Positive feedback responses do not maintain homeostasis because the effects produced do not reestablish set points. Instead, they quicken the rate at which effects can be produced and in this capacity they can be very helpful as a component of a negative feed back loop in maintaining homeostasis.

A. Resting Pulse Rate Negative Feedback Control And Normal Range

The resting cardiac and pulse rate, measured in beats per minute, is maintained in a state of dynamic constancy by negative feedback loops initiated by sensors in response to changes in blood pressure and other factors. Consistent with most regulatory processes several effectors are involved in the maintenance of pulse rate. Pulse rate is largely controlled by the variable activity of two different anatagonistic nerves. One nerve (sympathetic) stimulates an increase in cardiac rate while an antagonisitc nerve (parasympathetic) produces inhibitory effects that slow the cardiac rate. Therefore, the resting pulse rate is not absolutely constant but instead varies about a set-point value.

Procedure 1.A In this exercise, you will demonstrate that your pulse rate is in a state of *dynamic constancy* (implying negative feedback mechanisms), and you will determine your resting pulse rate set point as the average value of ten measurements.

1. Select a team mate to measure their heart rate;
   * Gently press your index and middle fingers (not your thumb) against the radial artery in their wrist until you feel a pulse. Alternatively, the carotid pulse in the neck may be used for these measurements.
2. The pulse rate is usually expressed as pulses per minute (ppm). However, only the number of pulses per 15-second interval need to be measured.
   * Record the number of pulses per 15-second intervals in the data table provided in the attached results section.
3. * Pause 15 seconds, and then take their pulse count for another 15-second interval.
   * Repeat this procedure over a 5-minute period.
   * A total of ten measurements will be obtained.
4. * Multiplying each 15 sec pulse by 4 to calculate the number of pulses per minute (ppm).
   * Record each pulse rate (expressed per minute) every 15 sec interval during the 5 minutes.
5. Calculate the average pulse rate for the ten recorded events: Average = Sum of all events / 10.
6. Using the grid provided in the laboratory report, graph your results by placing a dot at the point corresponding to the pulse rate for each measurement, and then connect the dots to demonstrate the heart rate fluctuations.

Normal Values :

Because the body's health is contingent upon its ability to regulate homeostasis, deviations from the normal consistency are clear indicators of abnormal function. In order to determine if a body parameter has deviated from "normal" or "healthy", reference *Normal or Healthy Values* must be established. Any parameter of the body subject to change or variation has associated a "normal value". Normal values are nothing more than the average values which are maintained by most "healthy" persons. These values are obtained through the careful and repetitive measurements of specific parameters of "healthy" persons. Since healthy people differ to some degree in their particular values, what is considered normal is usually expressed as a range of values that encompasses the measurements of *most* healthy people. An estimate of the normal range is a statistical determination (which we will explore next session). Therefore, *Normal Values* are used to assess the state of an individual's health.

Table 1 : Normal Valves

Arterial pH	7.35-7.45
Bicarbonate	24-28 mEq/L
Sodium	135-145 mEq/L
Glucose	75-110 mg/dl
Protein	6.5-8.0 g/dl

Healthy, in the context of heart rate, means the absence of cardiovascular disease. Included in the healthy category, however, are endurance-trained athletes, who usually have lower than average cardiac rates, and relatively inactive people, who have higher than average cardiac rates. Determinations of normal ranges can thus vary, depending on the relative proportion of each group in the sample tested. A given class of students may therefore have an average value and a range of values that differ somewhat from those of the general population.

CLINICAL SIGNIFICANCE

The concept of homeostasis is central to medical diagnostic procedures. Through the measurement of body temperature, blood pressure, concentrations of specific substances in the blood, and many other variables, the clinical examiner samples the internal environment. If a particular measurement deviates significantly from the normal range - that is, if homeostasis is not being maintained - the cause of the particular disease may be traced and proper treatment determined to bring the measurement back to the normal range.

Procedure 1.B

1. Each student in the class is to determine his or her own average pulse rate from the previous data by calculating an arithmetic average. Once calculated, record your average pulse rate on your data sheet and on the *overhead transparency in the front of the classroom*. Classify yourself into one of two groups 1. Exercise Group: those that exercise at least three times a week for 30 minutes and 2. Sedentary Group: those that exercise less than 3 times a week.

2. Record the average pulse rate for each student in the class in the data sheet provided. Record the data into the appropriate groupings: 1. *Exercise Group* : those who exercise on a regular basis and 2. *Sedentary Group*: those who do not exercise on a regular basis.

3. Calculate and record the overall class mean (average) pulse rate for the Exercise Group.

4. Calculate and record the overall class mean (average) pulse rate for the Sedentary Group.

Statistical Analysis:

Physiological measurements are collected, organized and graphed, but without a method of scientific analysis, these measurements are meaningless. Statistics offers a series of mathematical calculations that can be carried out on a set of data in order to determine its meaning.

The most frequently used statistical calculation is the **arithmetic mean** (average). The mean determines the most "central" value for all numbers in a set of data.

Mean (x) = sum of all values / # of values (n)

Example : Appendix length : 4cm, 3cm, 6cm, 5cm

Mean appendix length = _______cm

You used this calculation in the previous exercise to determine the most central value of your heart rate.

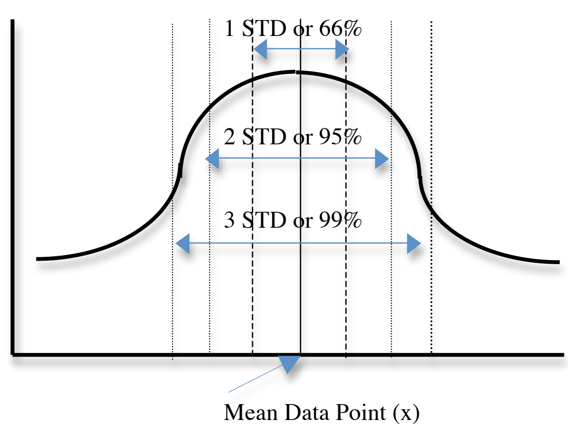
Standard Deviation (σ): Another frequently used statistical calculation is **Standard Deviation (σ)**. Standard deviation can only be used on a set of data in order to calculate how far away from the mean the data within the set deviates. Standard deviation is of particular importance in physiology because the calculation allows for the determination of "*Normal Values*". Standard deviation applies to a set of data in the following manner : If the data is normally distributed with most data falling around the mean, then :

Table 2 : Standard Deviation

66% of all data falls within one STD of the mean :
95% of all data falls within two STD of the mean :
99% of all data falls within three STD of the mean :
66% of all appendices are (4.5cm ± 1.29 cm) or are (3.21 to 5.79cm)
95% of all appendices are (4.5cm ± 2(1.29cm)) or are (1.92 to 7.08cm)
99% of all appendices are (4.5cm ± 3(1.29cm)) or are (0.63 to 8.37cm)

In determining "*Normal Values*" for physiological parameters, most published parameters utilize the *mean plus 2 units of standard deviation* (Mean +/- 2STD), thus encompassing 95% of the population tested. This means that for all those individuals tested which were healthy, 95% of them had values which deviated no more than 2 standard deviation from the mean. Therefore "Normal Values" encompass 95% of normal individuals.

Fig. 5
STD for Typical Data Set



Exercise 2.A : Which group has a more homogeneous set of appendices?

Group 1 :	Group 2:
5cm	1cm
5cm	2cm
3cm	7cm
6cm	10cm

1. Determine the mean for both groups :

Mean (x_1) for Group 1 = ________ Mean (x_2) for Group 2 = ________

2. Which group is a more homogeneous (similar)? ___________________

Calculation for Standard Deviation (σ) : In order to determine which group is *statistically* more variable, Standard Deviation can be used.

This calculation is a multi-step process: *Standard Deviation for group 1*

Step 1 : **A = (sum of all values)** n = *number of values*

$A = (5 + 5 + 3 + 6) = 19$

Step 2 : **B = (sum of the squares of all values)**

$B = (5^2 + 5^2 + 3^2 + 6^2) = 25 + 25 + 9 + 36 = 95$

Step 3 : **C = B - [A² / n]**

$C = 95 - [(19)^2 / 4] = 95 - (361 / 4) = 95 – 90.25 = 4.75$

Step 4 : **σ² = c / (n-1)**

$\sigma^2 = 4.75 / (4 -1) = 4.75 / 3 = 1.58$

$\sigma = \sqrt{\sigma^2} = \sqrt{1.58} = 1.26$

Normal Valves (95% confidence) for a particular set of data is expressed as the mean +/- the 2 STDs. Therefore the *normal values* for appendix length in group1 is 4.75cm +/- 2(1.26)cm or (2.23cm – 7.27 cm)

Exercise 2.B : Calculate the Mean and standard deviation for Group 2:

Step 1 : A = (sum of all values)

A =

Step 2 : B = (sum of the squares of all values)

B =

Step 3 : $C = B - [A^2 / n]$

C =

Step 4 : $\sigma^2 = c / (n-1)$

$\sigma^2 =$

$\sigma = \sqrt{\sigma^2} = \sqrt{\quad} =$

Mean (x_2) : ________ Standard Deviation (STD) : __________________

Normal Values for appendix lengths in group 2 = ____________________

<u>Clinical Significance :</u> In most physiological measurements, "NORMAL RANGES" are expressed as the mean and two standard deviations or 95% of ALL data collected (95% confidence).

ie. :	Human blood pH :	7.35 - 7.45
	Human blood Volume :	80 - 85 ml / kg body weight
	Human blood cholesterol :	120 -220 mg / ml

Answer for exercise 2.B : Mean x_2 = 5cm & STD = 4.24cm Normal Values = 0.0cm – 13.49cm (technically – 3.49, but appendices can't be negative in size)

<u>T – Test</u>: Another statistical test frequently applied to data is the *t – test*. The t – test is used to determine whether two different sets of data are *significantly different* from one another set with a *95% confidence*. A *t value* can be calculated from two sets of data and compared to a table of *t values*.

If the calculated t – value is GREATER than the table t – value, then the two sets of data are significantly different from one another (with 95% confidence).

Calculated t – value > table t – value = DIFFERENT

If the calculated t – value is LESS than the table t – value, then the two sets of data are NOT significantly different from one another (with 95% confidence).

Calculated t – value < table t – value = NOT DIFFERENT

The calculation of t – values utilizes the same variables as the calculation for STD :

$$t = \frac{|x_1 - x_2|}{\sqrt{\left(\frac{(C_1 + C_2)}{(n_1 + n_2 - 2)}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

In order to use the T – Table you need to determine the degrees of freedom (df) = $(n_1 + n_2 - 2)$

Example Calculation : The t – value for the appendices example is calculated as follows :

$$t = \frac{|4.75 - 5.0|}{\sqrt{\left(\frac{(4.75 + 54)}{(4 + 4 - 2)}\right)\left(\frac{1}{4} + \frac{1}{4}\right)}} = 0.113$$

$$df = (n_1 + n_2 - 2) = (4+4-2) = 6$$

The table t-value for this set of data is 2.45. Since the calculated value is less than the table valve there is NO difference in the data set (or appendix lengths between the 2 groups)

Procedure 2.A : Calculation of significant difference between collected class data.

1. Using the pulse rate data collected for both groups (Exercise & Sedentary Group), calculate the mean and standard deviation.
2. For each group determine the normal values (mean +/- 2 STDs)
3. Using the pulse rate data determine whether the two groups of are statistically different (95% confidence) by using the t – test. *Use the attached t – value table.*

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Name : ____

Introduction / Homeostasis

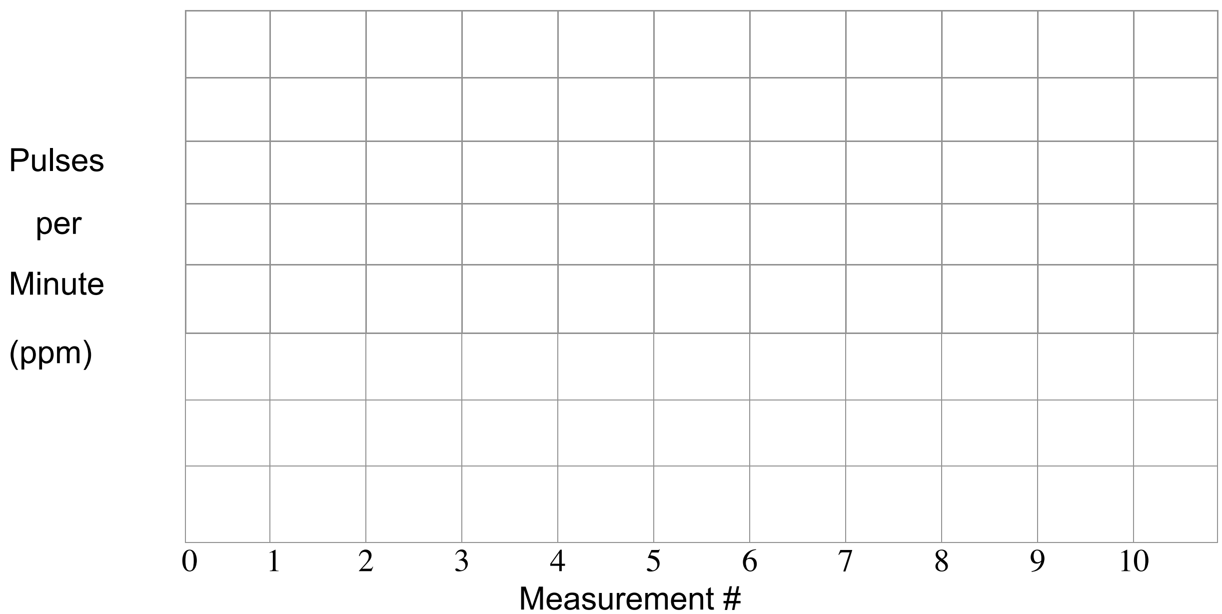
Laboratory Data :

Procedure 1.A : Resting Pulse Rate: Negative Feedback Control and Normal Range

Measurement	1	2	3	4	5	6	7	8	9	10	sum
Pulses / 15 sec											
Pulses/minute (ppm)											

1. Your average pulse rate:__________pulses per minute (ppm).

2. Results / Graph:



Procedure 1.B : Class pulse-rate averages:

Student #	Exercise (ppm)	Sedentary (ppm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		

Mean = X_E ___________ X_S _____________

Procedure 2.A : Calculation of significant difference between collected class data.

1a. Exercise Group :

Step 1 : A = (sum of all values)

A =

Step 2 : B = (sum of the squares of all values)

B =

Step 3 : $C = B - [A^2 / n]$

C =

Step 4 : $\sigma^2 = c / (n-1)$

$\sigma^2 =$

$\sigma = \sqrt{\sigma^2} = \sqrt{\quad\quad} =$

Mean (x_E) : ________ Standard Deviation (STD) : ___________________

Normal Values : __________________

1b. Sedentary Group :

Step 1 : A = (sum of all values)

A =

Step 2 : B = (sum of the squares of all values)

B =

Step 3 : $C = B - [A^2 / n]$

C =

Step 4 : $\sigma^2 = c / (n-1)$

$\sigma^2 =$

$\sigma = \sqrt{\sigma^2} = \sqrt{\quad\quad} =$

Mean (x_S) : ________ Standard Deviation (STD) : ___________________

Normal Values : __________________

2a. Determine if the two groups are statistically different from each other.

$$t = \frac{|x_1 - x_2|}{\sqrt{\left(\frac{(C_1 + C_2)}{(n_1 + n_2 - 2)}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

In order to use the T – Table you need to determine the degrees of freedom (df) = $(n_1 + n_2 - 2)$

Calculated t – value = _____________

df = ___________________________

2b. Utilize the above data and the attached t – table to determine if the data groups are significantly different from each other :

Are the data groups significantly different ? ______________

Lab Summary Questions

1. Briefly define the term homeostasis :

2. Briefly explain how your graph of pulse-rate measurements suggests the presence of a *dynamic consistency* rather than a static unchanging set point.

3. What is meant when two sets of data are described as being *significantly different* (how confident are you that there is truly a difference)? How would one go about determining if two sets of data are significantly different?

4. With your knowledge of adjustments routinely experienced during everyday occurrences, explain when negative feedback mechanisms would be utilized to monitor & adjust pulse rate, thus maintaining homeostasis. Draw a simple flow diagram to show how these feedback mechanisms. (hint : Think of what situations would cause the heart rate to increase and which would cause it to be stimulated to decrease.)

5. The normal range for a healthy resting pulse rate is 70 +/- 8 ppm. Describe, in general, how the normal range for a given measurement is obtained. Compare the normal ppm values to those obtained in class. Explain why some individuals may fall outside of this range and yet still be considered healthy.

6. What is a “Normal Value”? Why are “Normal Values” so important in the health field?

7. Examine the t – table. What happens to the t – value as the number of data points (n) increases? How would this affect the setup of an experiment – should you strive to have large or small data sets?

Table of t – Values

Degrees of freedom (df)	T - Value
1	12.71
2	4.30
3	3.18
4	2.78
5	2.57
6	2.45
7	2.36
8	2.31
9	2.26
10	2.23
11	2.20
12	2.18
13	2.16
14	2.14
15	2.13
16	2.12
17	2.11
18	2.10
19	2.09
20	2.09
21	2.08
22	2.07
23	2.07
24	2.06
25	2.06
26	2.06
27	2.05
28	2.05
29	2.04
30	2.04
35	2.03
40	2.02
45	2.02
50	2.01
100	1.98

✭ Determined for 95% confidence levels

✭ Degrees of freedom = (df) = $(n_1 + n_2 - 2)$