Handout B: Electrocardiography (ECG)
S223: Intro to Human Cardiology

NOTE: read *Van Meter & Lavine, Chapter 1* before this section.

Now that you have a general understanding of what an ECG is, we can begin exploring how to analyze electrocardiograms. First it is necessary to know what a normal, healthy ECG looks like. Once that is established, we will cover a variety of electrocardiographic abnormalities, including:

- *Arrest intervals*
- *Atrial fibrillation*
- *Atrial flutter*
- *Atrial tachycardia*
- *Sinus arrest*
- *Sinus arrhythmia*
- *Sinus bradycardia*
- *Sinus tachycardia*
- *Ventricular fibrillation*
- *Ventricular tachycardia*

Please note that this is only a *sample* of some of the more common ECG abnormalities. Electrocardiograms are often much more nuanced and multifaceted; but for the purposes of this course, we will focus on the stereotypes.

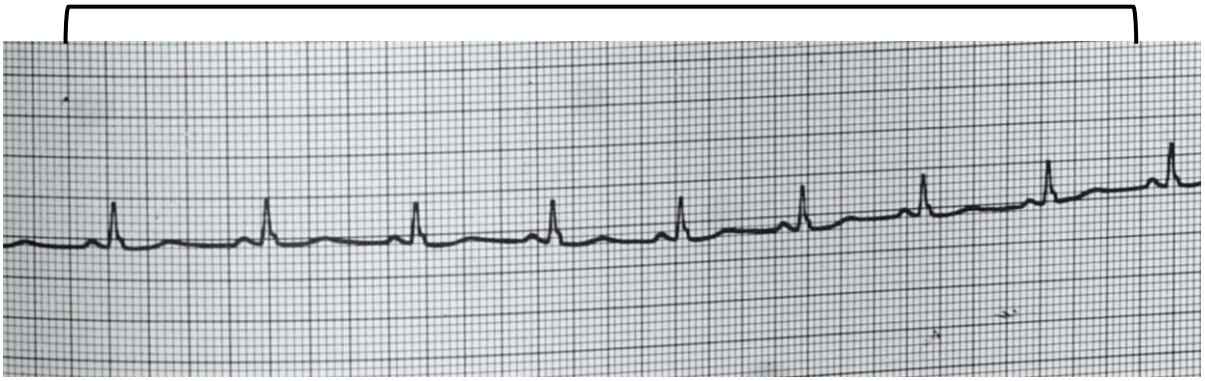
"*Heart Rate:*" *Atrial vs. Ventricular*

The terms *heart rate* or *pulse rate* generally refer to the number of times the heart beats in a minute (units: beats per minute [bpm], often written simply as " /min"). More technically, this measurement can be broken up into *atrial rate* and *ventricular* rate—*i.e.*, the rate at which the atria (upper chambers) and ventricles (lower chambers) pass blood. Atrial rate is typically measured as the ***number of P waves per minute***, whereas ventricular rate is typically measured as the ***number of QRS complexes per minute***. Ventricular rate is *usually* the more relevant of the two, since the [left] ventricle is the major point of muscular contraction in the heart (it is from this point that blood must be pushed through the aortic arch and perfuse the entire body). Under abnormal circumstances (*i.e.*, when the P wave is absent), atrial and ventricular rates can be unequal.

Case A. NORMAL SINUS RHYTHM

For the purposes of this class, we will only focus on measuring *ventricular rate* (*i.e.*, the number of QRS complexes per minute). One of the quickest (albeit also less accurate) methods of inferring ventricular rate is to count the number of QRS complexes manually in a six-second interval, and then multiple by ten to yield your value in bpm. Below is an example of a six-second snapshot of a *normal sinus rhythm*.

(6 *sec*.)



(*please ignore the apparent curvature of the strip; image was scanned imperfectly*)

1. Count the number of QRS complexes captured in the six-second window;
2. Then, multiple that number by ten.
3. What did you get?

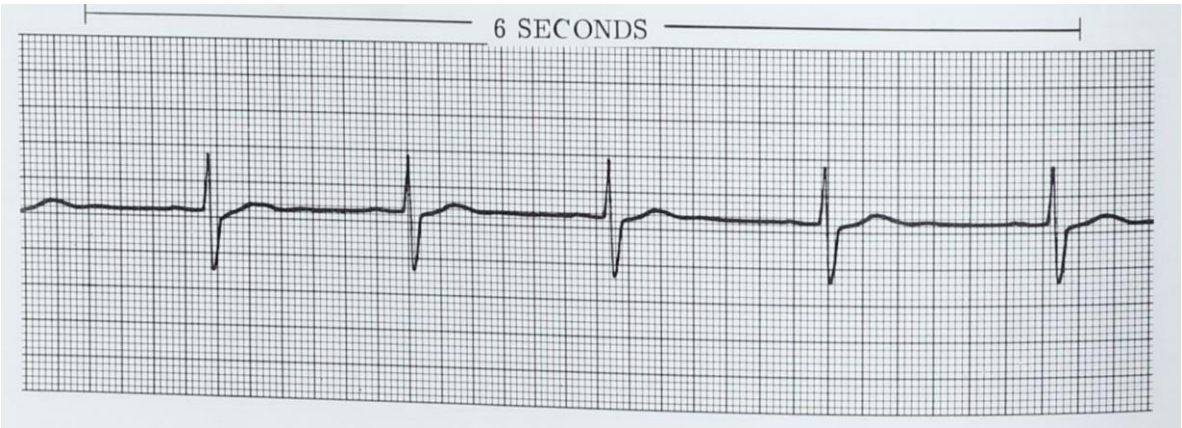
(A) 70 /min.
(B) 80 /min.
(C) 90 /min.
(D) None of the above

If you answered "C: 90 /min.," you are absolutely correct! However, if you answered "B: 80 /min.," I would also accept your answer. Notice the position of the measure bar indicating the six-second range: is it roughly centered over the sinus rhythm? One of the defining features of a *normal sinus rhythm* is **regularity**—that is, even spaces between each of the QRS complexes. As such, the answer "90 /min." is *slightly more correct* than 80 /min. because shifting the six-second window to the right ever so slightly would center it over the rhythm and capture nine QRS complexes instead of eight. This is a rough estimate, so anywhere in the 80–90 /min. range is approximately right. In a hospital setting, sophisticated ECG monitors can more accurately measure this dynamic in real-time.

Case B. SINUS ARRHYTHMIAS

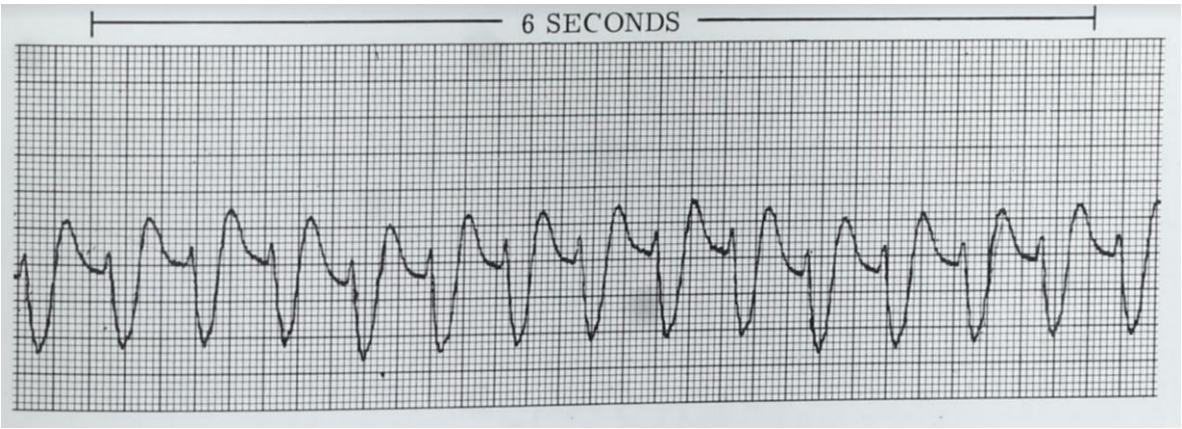
The rate of cardiac pulsation is largely influenced by the innervation (*i.e.*, activation) of the *vagus nerve*. The term 'vagal tone' is often used to describe the rhythm of this nerve's activity. The term ***sinus rhythm*** refers to the rhythm of activity through the sinoatrial (SA) node. ***Sinus arrhythmias*** refer to *abnormal* SA rhythms that result in a ventricular rate that is either too slow, too fast, or irregular.

Bradycardia is defined as a ventricular rate below 60 /min. E.g.,



(*Ventricular rate* = 50 /min.)

Tachycardia is defined as a ventricular rate above 100 /min. E.g.,

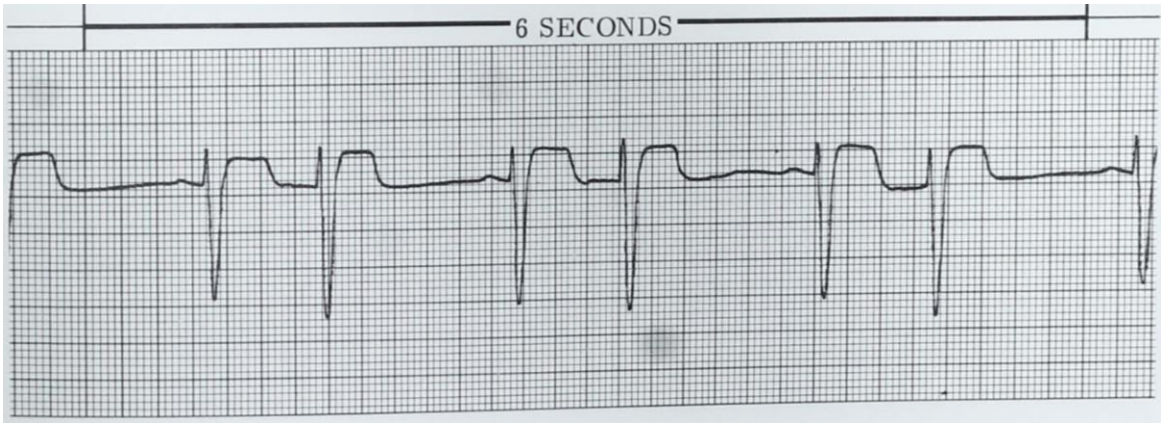


(*Ventricular rate* = 130 /min.)

This is an example of *ventricular tachycardia*, which is discussed more in pg. 8.

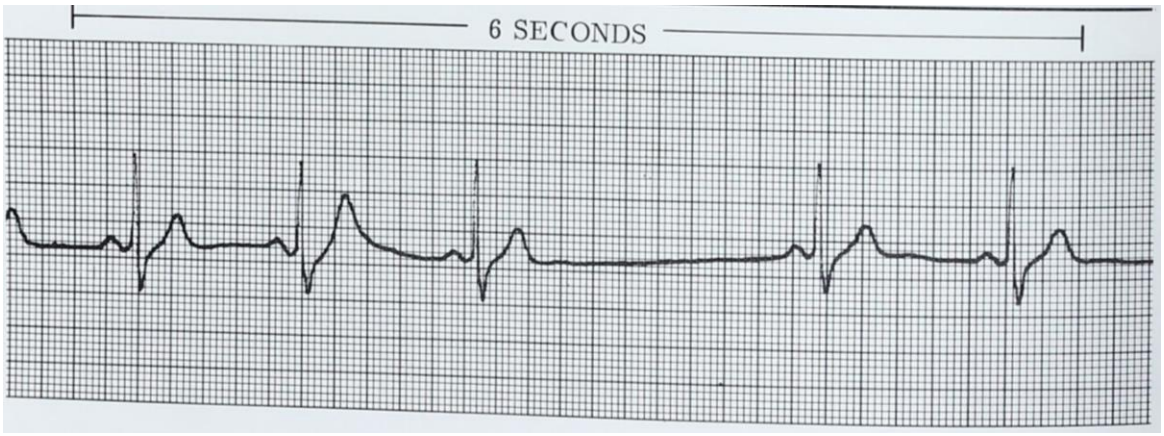
Finally, a ***normal sinus rhythm*** is defined in part by a ventricular rate between 60 and 100 /min. However, not all ventricular rates within this range are "normal;" they must also be *regular*—or have equal spacing between QRS complexes. The two examples above are both examples of *regular* cardiac contraction.

Below is an example of a rhythm that is *irregular*. The exact specification of this rhythm is a ***bigeminal rhythm***, which is a condition in which cardiac rhythm fluctuates continuously (*i.e.*, not episodic) between long and short QRS–QRS intervals. This rhythm is associated with numerous disorders, such as coronary artery disease, cardiomyopathy, thyroid dysfunction, or hereditary disorders.



(*Ventricular rate* = 60 /min.)

Here is another example of an irregular rhythm. In this case, the irregularity is confined to one prolonged rest approximately midway through the strip.

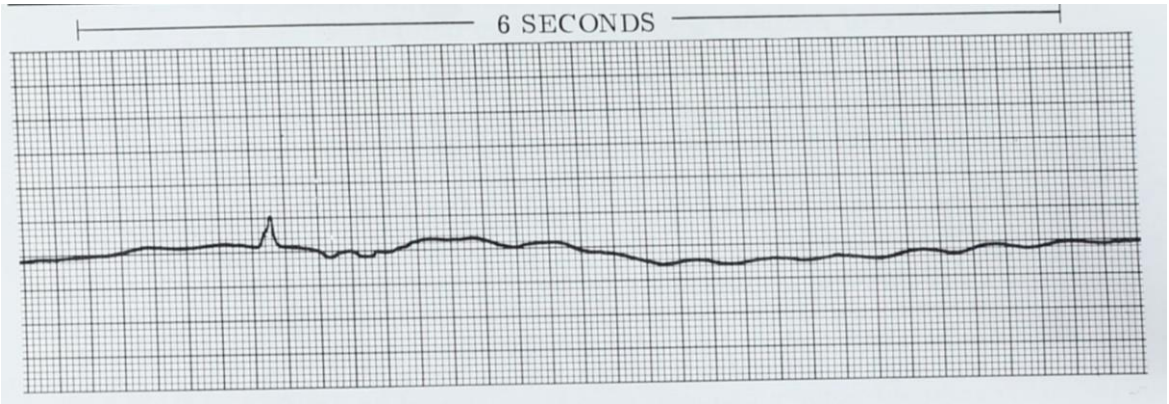


(*please ignore the apparent curvature of the strip; image was scanned imperfectly*)
(*Ventricular rate* = 50 /min.)

Electrocardiographic irregularities may appear in a wide variety of patients. Conduction defects and electrical asynchronization are some of the many causes. For the purposes of this course, we will focus solely on discriminating between "regular" and "irregular" samples.

Case C. SINUS ARREST

Sinus arrest is defined as the absence of sinoatrial (SA) conduction, resulting in an absence of organized cardiac contraction (as well as QRS complexes). Sinus arrest may also be called "sinus pause," "sinus standstill," or more colloquially as "flatlining." Below is an example of sinus arrest:

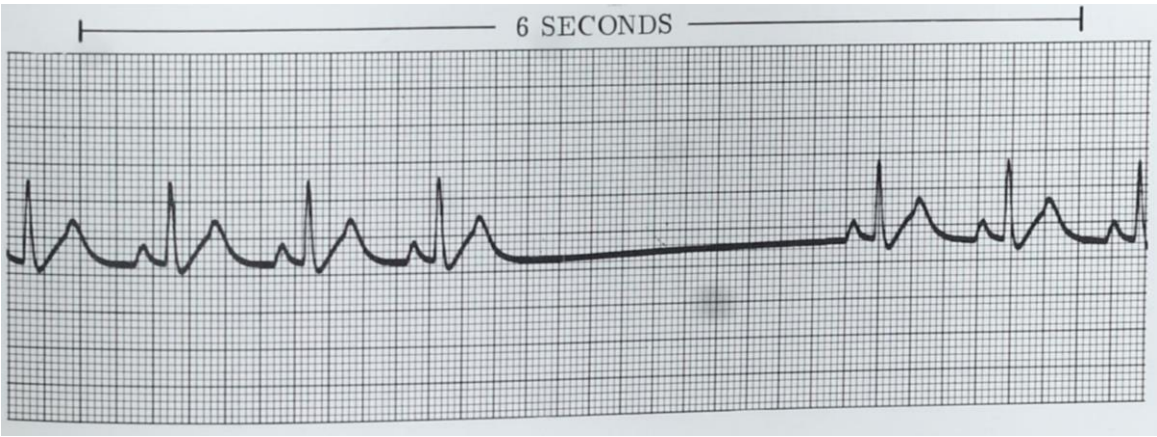


(*please ignore the apparent curvature of the strip; image was scanned imperfectly*)
(*Ventricular rate* = N/A or 10 /min.)

Although sinus arrest is a feature of clinical death, many patients can recover from this loss of rhythmicity, and it may even be induced temporarily during surgical procedures. During electrical defibrillation (which will be discussed more later), sinus arrest is transiently induced in order to give the heart a chance to "reboot." A common misconception is that defibrillation restarts a heart that has already stopped beating. In actuality, defibrillation is essentially ineffective for most cases of sinus arrest; rather, it can be useful for *stopping* an abnormal rhythm.

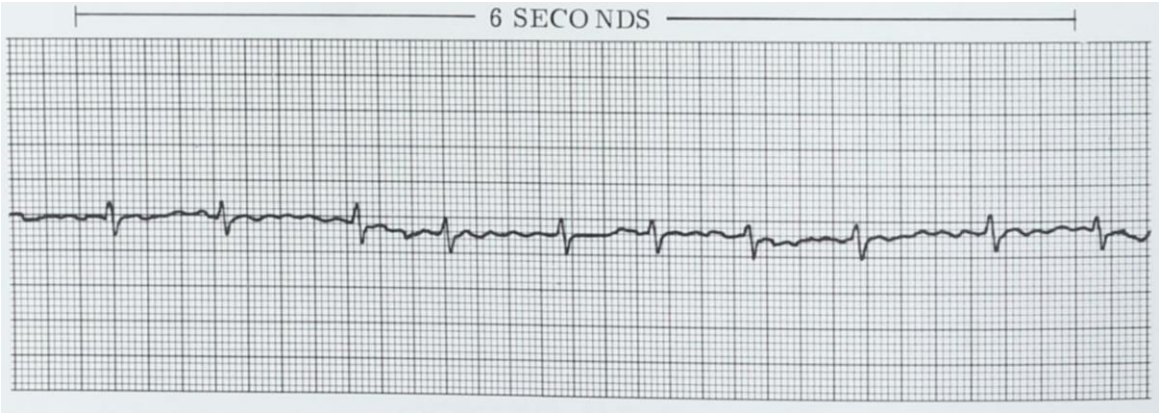
Case D. ARREST INTERVAL

Other times, sinus arrests can occur in discrete intervals and resolve spontaneously. Below is an example of an otherwise regular rhythm that is interrupted by a long sinus pause between the third and fourth QRS complexes:



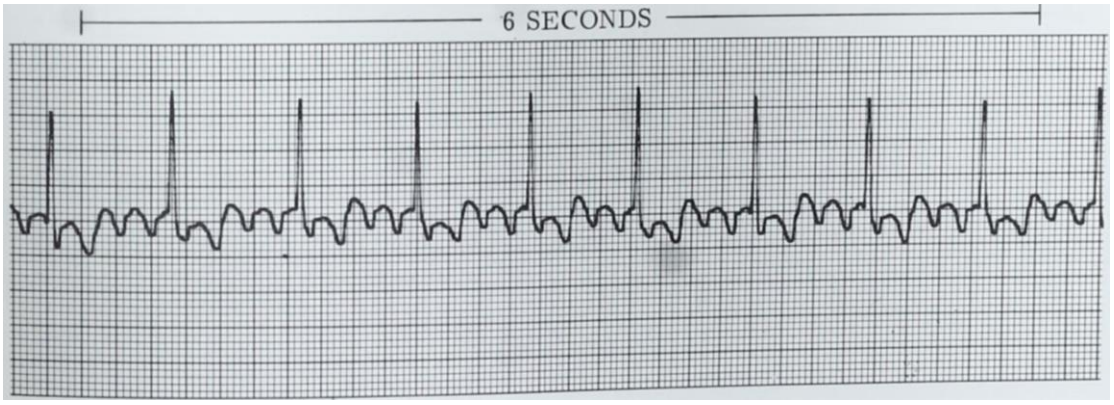
Case E. ATRIAL FIBRILLATION

Atrial fibrillation is a condition in which the *atria* of the heart beat irregularly. The atria often beat rapidly and more chaotically than normal. It is therefore an example of "supraventricular tachycardia." Normally, the atria (two upper chambers of the heart) rhythmically push blood down into the *ventricles* (two lower chambers of the heart). Fibrillation occurs when electrical activity in the atria becomes disorganized and hyperactive, often resulting in atrial muscular (auricular) contractions that are rapid but not synchronized. This can lead to poor perfusion (blood flow); however, it can also be asymptomatic.



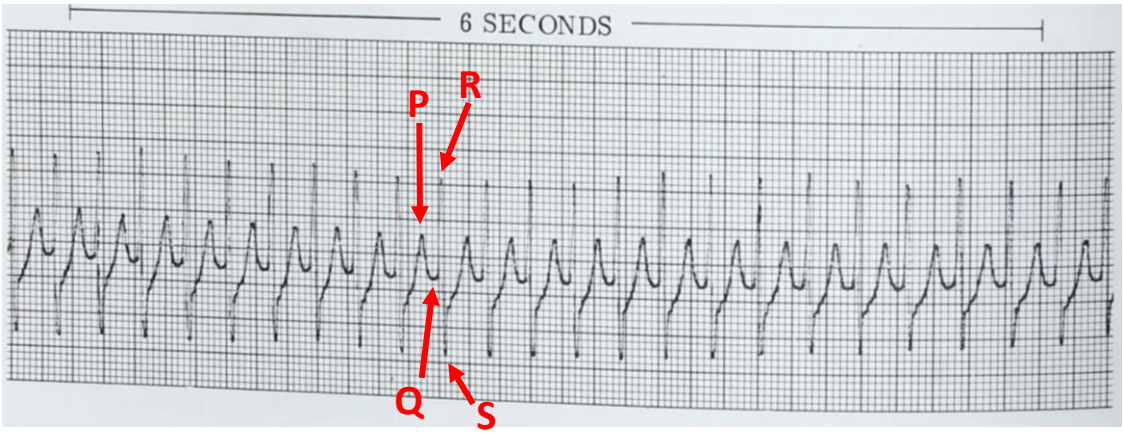
Case F. ATRIAL FLUTTER

Atrial flutter can easily be confused with atrial fibrillation since both are examples of supraventricular tachycardia; however, atrial flutter is generally regular and appears with a rapid onset of symptoms, including dizziness, fainting, and chest discomfort. This condition can occur from hypertension (high blood pressure), diabetes, coronary artery disease, among other things. Also, *P* waves are often present in atrial flutter but are often absent in atrial fibrillation.



Case G. ATRIAL TACHYCARDIA

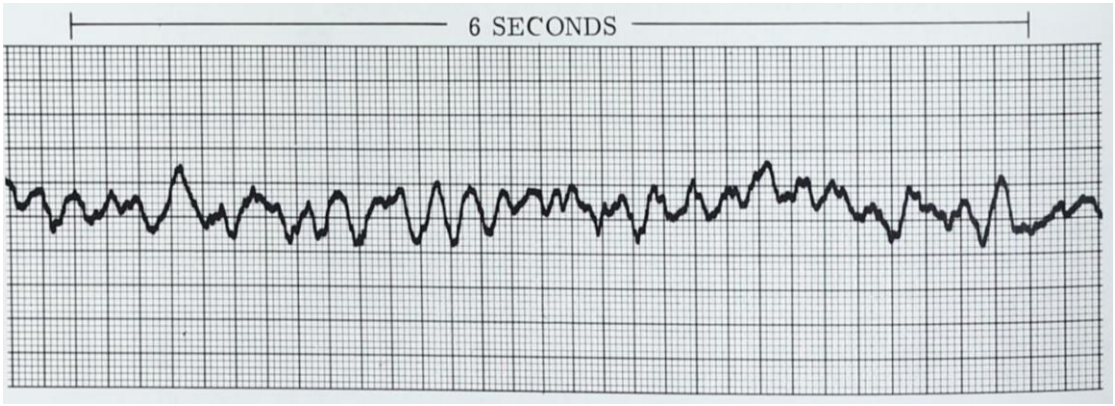
Atrial tachycardia is yet another form of supraventricular tachycardia defined by a regular ventricular rate, typically in the range of 140–220 /min., whereas sinus tachycardia usually involves rates of 100–140 /min. This is often caused from a premature electrical impulse in the atria and can lead to atrial fibrillation (a more severe condition defined by loss of regularity). A key feature of atrial tachycardia is narrow QRS complexes. Compare this trace with the longer QRS intervals in *sinus tachycardia* (PAGE 3).



(*Ventricular rate* = 210 /min.)

Case H. VENTRICULAR FIBRILLATION

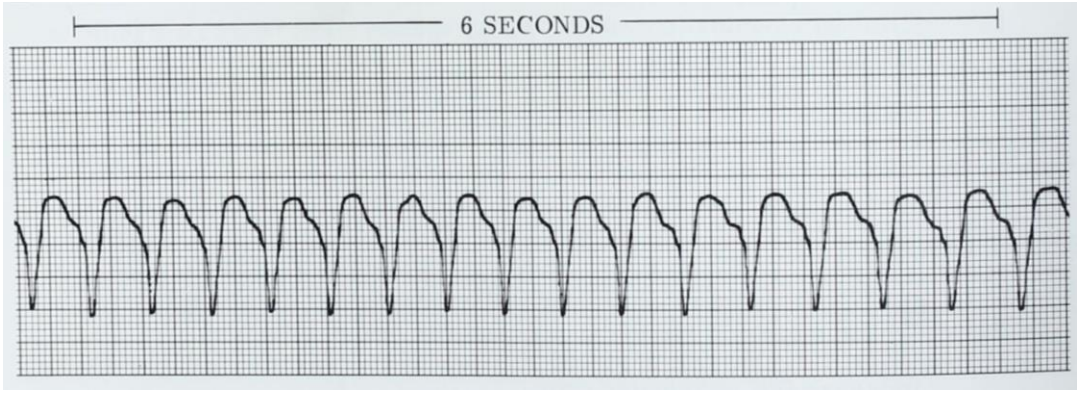
Ventricular fibrillation is a life-threatening condition in which electrical activity in the ventricles becomes disorganized, irregular, and noncooperative. It is defined electrocardiographically by an absence of clear QRS complexes or distinct *P* waves. Without <u>immediate</u> treatment (CPR and defibrillation), this rhythm decays into cardiac arrest and death. Patients in ventricular fibrillation ("V-fib") generally do not have a palpable pulse.



(*Ventricular rate* = ***undefined***—no clear QRS complexes)

Case I. VENTRICULAR TACHYCARDIA

Ventricular tachycardia ("V-tach") is yet another form of supraventricular tachycardia defined by a regular, rapid ventricular rate. This life-threatening condition arises from electrical dysregulation in the ventricles. It is defined by a ventricular rate of at least 120 /min. and at least three widened QRS complexes in a row.



(*Ventricular rate* = 150 /min.)