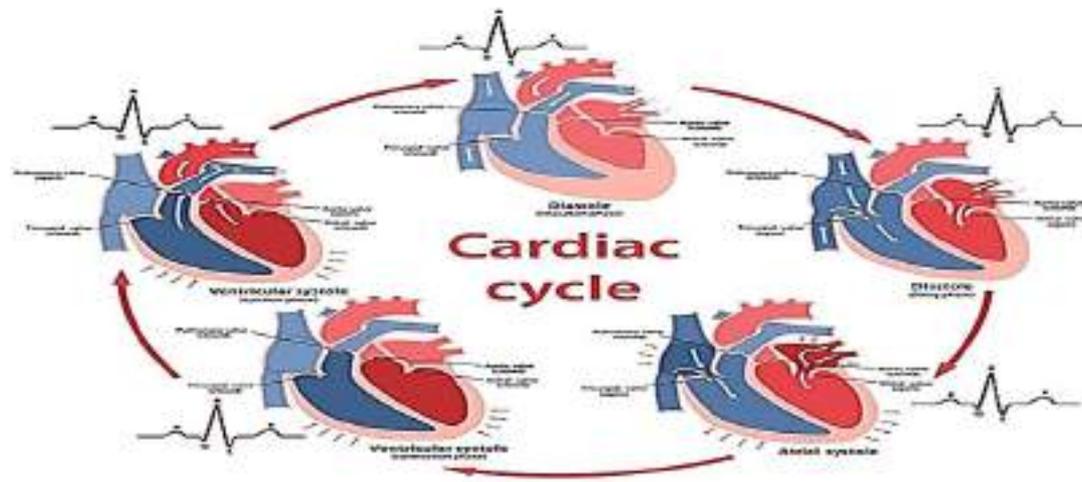


CVS MODULE PHYSIOLOGY (LECTURE 4) CARDIAC CYCLE

BY

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CARDIAC CYCLE

▪ **Definition of cardiac cycle:**

Cardiac cycle means the mechanical events occurring in the heart within one beat (from the beginning of a heart beat to the next one).

▪ **The cycle is divided into two major phases, both named for events in the ventricles:**

✓ **The period of ventricular contraction and blood ejection is called systole.**

✓ **The alternating period of ventricular relaxation and blood filling is called diastole.**

✓ **So, the cardiac cycle consists of one cycle of ventricular systole and diastole.**

▪ **For a heart rate of 75 beats/min, each cardiac cycle lasts approximately 0.8 second, with about 0.3 seconds in systole and 0.5 seconds in diastole.**

▪ **↑ HR → ↓ cardiac cycle duration and vice versa.**

▪ **Changes in cardiac cycle duration affects mainly diastole. This is important because filling of the ventricles & coronaries occur during the diastole .**

Mechanical Events of the Cardiac Cycle

- Both ventricular systole and diastole can be subdivided into two discrete periods.
- During the first part of systole, the ventricles are contracting but all valves in the heart are closed and so no blood can be ejected. This period is termed **isovolumetric ventricular contraction** because the **ventricular volume is constant**. The ventricular walls are developing tension and squeezing on the blood they enclose, increasing the ventricular blood pressure.
- However, because the volume of blood in the ventricles is constant and because blood is essentially incompressible, the ventricular muscle fibers cannot shorten. Thus, isovolumetric ventricular contraction is analogous to an isometric skeletal muscle contraction; the muscle develops tension, but it does not shorten.

- **Once the increasing pressure in the ventricles exceeds that in the aorta and pulmonary trunk, the aortic and pulmonary valves open and the ventricular ejection period of systole occurs. Blood is forced into the aorta and pulmonary trunk as the contracting ventricular muscle fibers shorten.**
- **During the first part of diastole, the ventricles begin to relax and the aortic and pulmonary valves close.**
- **At this time, the AV valves are also closed; therefore, no blood is entering or leaving the ventricles.**
- **Ventricular volume is not changing, and this period is called isovolumetric ventricular relaxation.**

- **Note, then, that the only times during the cardiac cycle that all valves are closed are the periods of isovolumetric ventricular contraction and relaxation.**
- **Next, the AV valves open and ventricular filling occurs as blood flows in from the atria.**
- **Atrial contraction occurs at the end of ventricular diastole, after most of the ventricular filling has taken place.**
- **The ventricle receives blood throughout most of diastole, not just when the atrium contracts.**

Mid- to Late Ventricular Diastole

Analysis of events in the left atrium and left ventricle and the aorta with the events of mid- to late diastole (Events on the right side of the heart are very similar except for the absolute pressures):

- The left atrium and ventricle are both relaxed, but **atrial pressure is slightly higher than ventricular pressure because the atrium is filled with blood that is entering from the veins.**
- **The AV valve is held open by this pressure difference,** and blood entering the atrium from the pulmonary veins continues on into the ventricle.
- At this time, and **throughout all of diastole, the aortic valve is closed because the aortic pressure is higher than the ventricular pressure.**
- **Throughout diastole, the aortic pressure is slowly decreasing because blood is moving out of the arteries and through the vascular system.**
- **Ventricular pressure is increasing slightly because blood is entering the relaxed ventricle from the atrium, thereby expanding the ventricular volume.**
- ✓ **About 70-80% of the ventricular filling occurs passively during diastole.**

- **The rate of filling declines** as the ventricles become distended and, the cusps of the AV valves drift toward the closed position.
- Near **the end of diastole**, the **SA node discharges** and the **atria depolarize**, as signified by the **P wave of the ECG**.
- Contraction of the atrium (**atrial systole**) causes an **increase in atrial pressure**.
- The **elevated atrial pressure** forces a small additional volume of **blood into the ventricle**, sometimes referred to as the **“atrial kick.”**
- This brings to the end of ventricular diastole, so **the volume of blood in the ventricle at this time is called the end-diastolic volume (EDV)**.

Mid to - late ventricular diastole includes the following phases:

- ✓ **Rapid filling phase.**
- ✓ **Slow filling phase.**
- ✓ **Atrial systole phase.**

VENTRICULAR SYSTOLE

Thus far, the ventricle has been relaxed as it fills with blood. But immediately following the atrial contraction, the ventricles begin to contract.

- From the AV node, the wave of depolarization passes into and throughout the ventricular tissue—as signified by the QRS complex of the ECG—and this triggers ventricular contraction.
- As the ventricle contracts, ventricular pressure increases rapidly; almost immediately, this pressure exceeds the atrial pressure.
- This change in pressure gradient forces the AV valve to close, thus preventing the backflow of blood into the atrium.
- Because the aortic pressure still exceeds the ventricular pressure at this time, the aortic valve remains closed and the ventricle cannot empty despite its contraction.
- ✓ For a brief time, all valves are closed during this phase of isovolumetric ventricular contraction (lasts about 0.05 second).
- ✓ During isovolumetric contraction, the AV valves bulge into the atria, causing a small but sharp rise in atrial pressure.

- This brief phase ends when the **rapidly increasing pressures in the left and right ventricles exceed the pressures in the aorta (80 mm Hg) and pulmonary artery (10 mm Hg) and the aortic and pulmonary valves open and ventricular ejection begins.**
- **Ventricular ejection is rapid at first and then slows down.**
- **The intraventricular pressure rises to a maximum and then declines somewhat before ventricular systole ends.**
- **Peak pressures in the left and right ventricles are about 120 and 25 mm Hg, respectively.**
- **Late in systole, pressure in the aorta actually exceeds that in the left ventricle.**
- **The AV valves are pulled down by the contractions of the ventricular muscle, and atrial pressure drops.**

- **The volume of blood ejected from each ventricle during systole is called the stroke volume (SV), it is about 70–90 ml at rest .**
- **The end-diastolic ventricular volume (EDV) is about 130 ml.**
- **About 50 ml of blood remains in each ventricle at the end of systole (end-systolic ventricular volume; ESV).**
- **Thus,**

Stroke volume = End-diastolic volume – End-systolic volume

$$\text{SV} = \text{EDV} - \text{ESV}$$

- **The ejection fraction = ratio of SV to EDV. It is normally about 65%.**
- **The ejection fraction is a valuable index of ventricular function.**

VENTRICULAR SYSTOLE

includes the following phases:

- ✓ **Isovolumetric (isometric) ventricular contraction phase.**
- ✓ **Maximum (rapid) ejection phase.**
- ✓ **Reduced ejection phase.**

Early ventricular diastole

Diastole begins as the ventricular muscle relaxes and ejection comes to an end.

- **The T wave of the ECG corresponds to ventricular repolarization.**
- **A period of protodiastole lasts about 0.04 second.**

Isovolumetric ventricular relaxation phase:

- **As the ventricles relax, the ventricular pressure decreases (around zero) below aortic pressure.**
- **The change in the pressure gradient forces the aortic valve to close (dicrotic notch).**
- **The AV valve also remains closed because the ventricular pressure is still higher than atrial pressure.**
- **For a brief time, then, all valves are again closed during this phase of isovolumetric ventricular relaxation.**

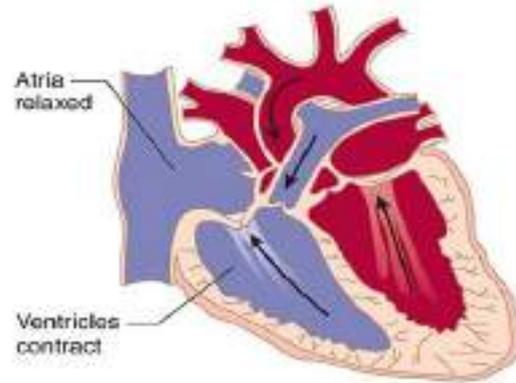
- **Isovolumetric relaxation ends when the ventricular pressure falls below the atrial pressure and the AV valves open, permitting the ventricles to fill.**
- **Filling is rapid at first, then slows as the next cardiac contraction approaches.**
- **Atrial pressure continues to rise after the end of ventricular systole until the AV valves open, then drops and slowly rises again until the next atrial systole.**

Early ventricular diastole includes the following phases:

- **Protodiastole phase.**
- **Isovolumetric (isometric) relaxation phase.**

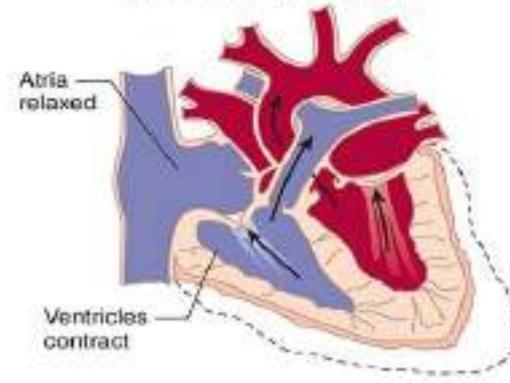
A Systole

Isovolumetric ventricular contraction



AV valves:	Closed
Aortic and pulmonary valves:	Closed

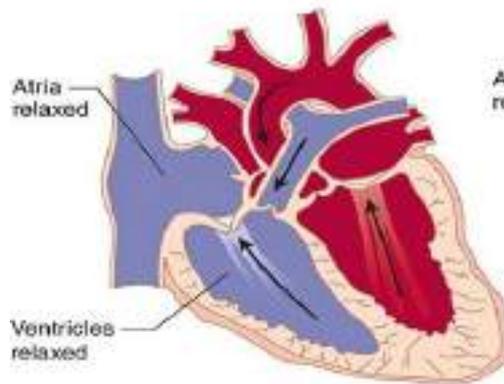
Ventricular ejection
Blood flows out of ventricle



AV valves:	Closed
Aortic and pulmonary valves:	Open

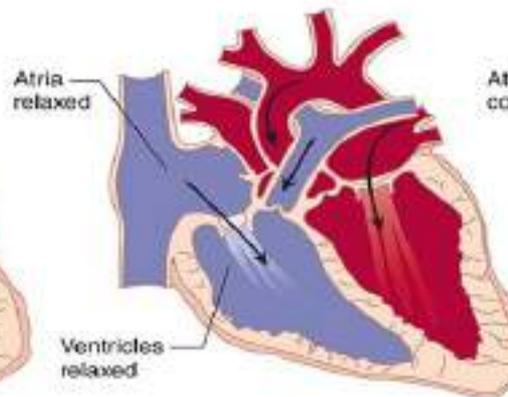
B Diastole

Isovolumetric ventricular relaxation



AV valves:	Closed
Aortic and pulmonary valves:	Closed

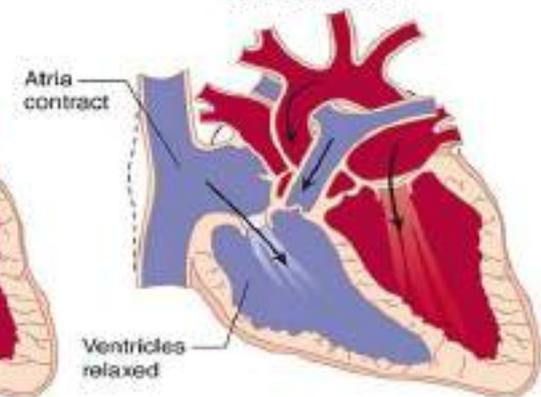
Ventricular filling
Blood flows into ventricles



Atria relaxed
Ventricles relaxed

AV valves:	Open
Aortic and pulmonary valves:	Closed

Atrial contraction



Atria contract
Ventricles relaxed

AV valves:	Open
Aortic and pulmonary valves:	Closed

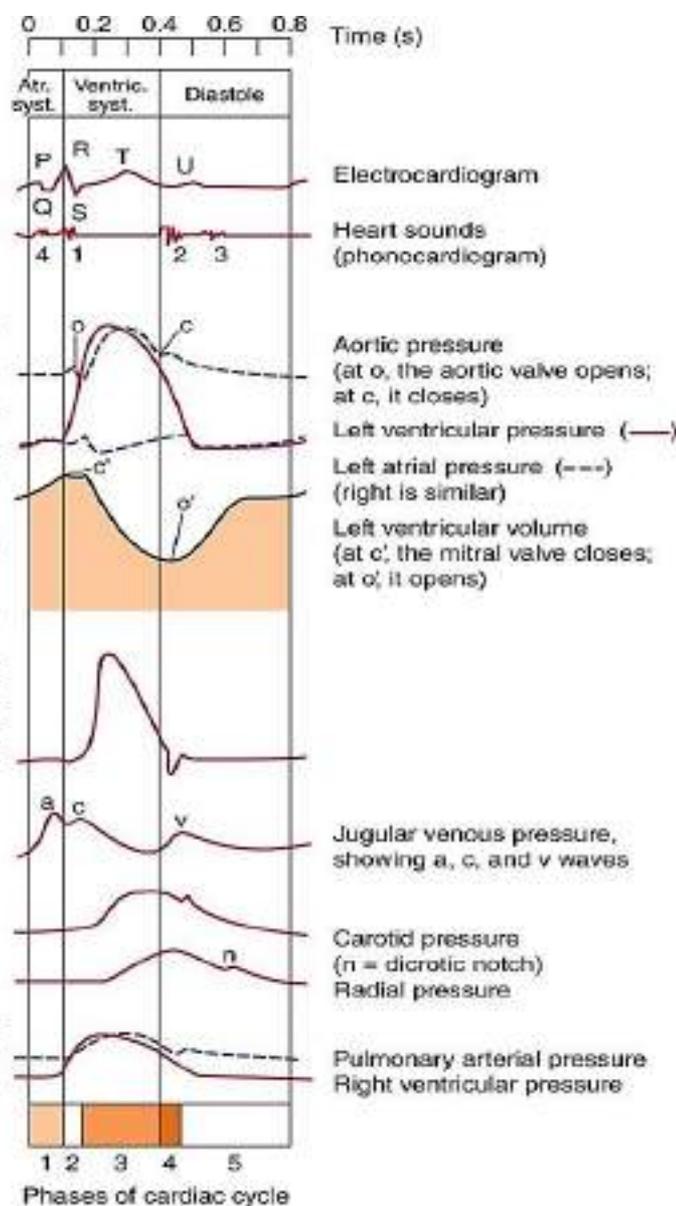


FIGURE 30–3 Events of the cardiac cycle at a heart rate of 75 beats/min.

The phases of the cardiac cycle identified by the numbers at the bottom are as follows: 1, atrial systole; 2, isovolumetric ventricular contraction; 3, ventricular ejection; 4, isovolumetric ventricular relaxation; 5, ventricular filling.

Note that late in systole, aortic pressure actually exceeds left ventricular pressure. However, the momentum of the blood keeps it flowing out of the ventricle for a short period. The pressure relationships in the right ventricle and pulmonary artery are similar.

FIGURE 30–3 Events of the cardiac cycle at a heart rate of 75 beats/min.

- ✓ The fact that most ventricular filling is completed during early diastole is of great importance.
- ✓ However, when heart rates of approximately 200 beats/min or more are reached, filling time becomes inadequate and the volume of blood pumped during each beat decreases.
- ✓ Early ventricular filling also explains why the defects that eliminate the atria as effective pumps do not seriously impair ventricular filling, at least in otherwise healthy individuals at rest.
- ✓ This is true, for example, of atrial fibrillation, a state in which the cells of the atria contract in a completely uncoordinated manner and so the atria fail to work as effective pumps.

TIMING

- ✓ Although events on the two sides of the heart are similar, they are somewhat asynchronous.
- ✓ Right atrial systole precedes left atrial systole, whereas contraction of the right ventricle starts after that of the left.
- ✓ However, since pulmonary arterial pressure is lower than aortic pressure, right ventricular ejection begins before that of the left.
- ✓ During expiration, the pulmonary and aortic valves close at the same time; but during inspiration, the aortic valve closes slightly before the pulmonary valve.
- ✓ When measured over a period of minutes, the outputs of the two ventricles are, of course, equal, but transient differences in output during the respiratory cycle occur in normal individuals.

Phonocardiogram

The phonocardiogram is an acoustical recording reflecting the heart sounds generated during the cardiac cycle.

Heart Sounds:

Two sounds are normally heard through a stethoscope during each cardiac cycle.

- The first is a soft, low pitched and slightly prolonged “lub” (**first sound; S1**), caused by **vibrations set up by the sudden closure of the AV valves at the start of ventricular systole (Isovolumetric contraction phase & first part of maximum ejection phase).**
- The second is a shorter, high-pitched “dub” (**second sound; S2**), caused by vibrations associated with **closure of the aortic and pulmonary valves at early ventricular diastole (Isovolumetric relaxation phase).**
- Lub marks the onset of systole and the dub occurs at the onset of diastole.

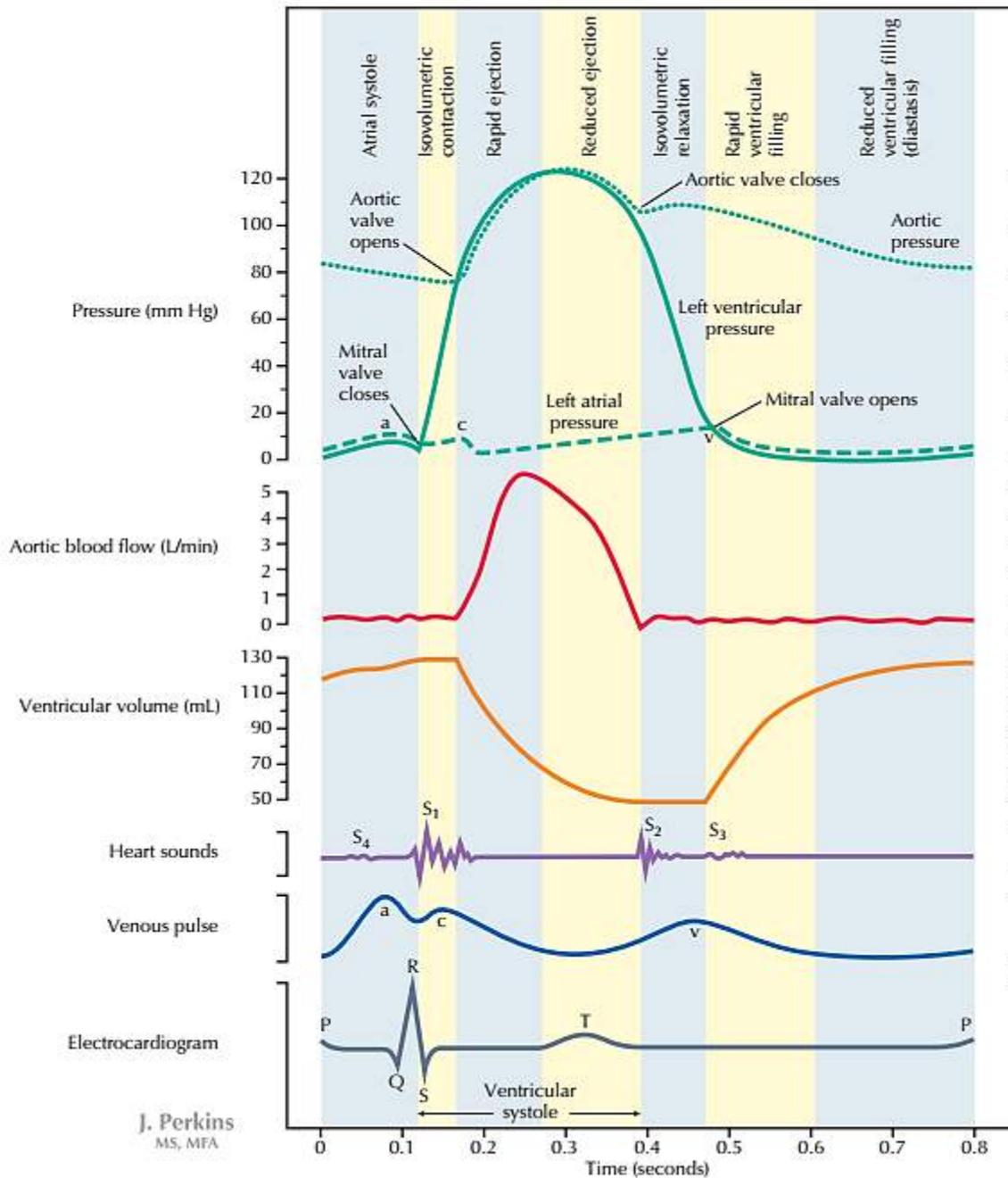
During inspiration, closure of the pulmonic valve is delayed more distinctly, normally resulting in audible physiological splitting of S2. This delay is caused by increased filling of the right ventricle, due to reduced intrathoracic pressure during inspiration.

S3, the third heart sound, is normal in children, and is associated with **rapid ventricular filling**. It is not heard in normal adults.

S4, caused by **active ventricular filling (atrial systole phase)**, also is not audible in normal adults.

Some remarks on cardiac cycle

- **70-80% of ventricular filling occurs passively during rapid and slow filling phases. Only 20-30% of blood is actively pumped into ventricle during atrial systole.**
- **Highest pressure in the left ventricle is about 120 mmHg.**
- **Highest pressure in the right ventricle is about 25 mmHg.**
- **Aortic and pulmonary valves are open during:**
Maximum (rapid) ejection, reduced ejection and protodiastole phases.
- **A-V valves are open during:**
Rapid filling, slow filling, and atrial systole phases.
- **All valves are closed during: Isovolumetric contraction and Isovolumetric ventricular relaxation phases.**
- **Opening of all valves doesn't occur normally.**
- **Valves make sound during their closure not during their opening.**



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Thank
you

The image features the words "Thank you" written in a highly decorative, cursive script. The letters are a dark teal color with a white outline and a soft grey drop shadow, giving them a three-dimensional appearance. The text is centered and surrounded by a dense arrangement of colorful floral and leaf motifs. These include small pink and red flowers, orange and yellow leaves, and green sprigs with small buds. The overall composition is vibrant and celebratory, set against a plain white background.